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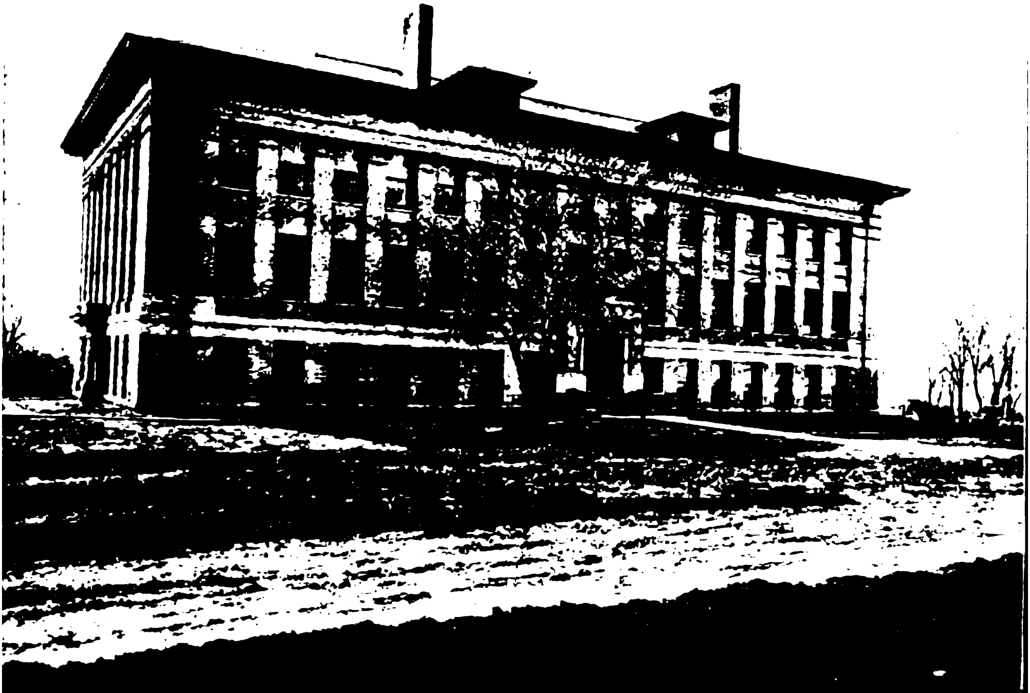

Annual Report

University of Nebraska (Lincoln campus).
Agricultural Experiment Station

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THE UNIVERSITY OF NEBRASKA

NINETEENTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF

NEBRASKA

PRESENTED TO THE GOVERNOR FEBRUARY 1, 1906

THE UNIVERSITY OF NEBRASKA

NINETEENTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF

NEBRASKA

PRESENTED TO THE GOVERNOR FEBRUARY 1, 1906

LINCOLN, NEBRASKA
U. S. A.

V 4611

LETTER OF TRANSMITTAL.

NEBRASKA AGRICULTURAL EXPERIMENT STATION,
THE UNIVERSITY OF NEBRASKA.

To His Excellency, J. H. Mickey, Governor of Nebraska:

SIR—In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Nineteenth Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
Director.

The University of Nebraska, February 1, 1906.

GOVERNOR'S CERTIFICATE.

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT,
LINCOLN, FEBRUARY 1, 1906.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR—I hereby acknowledge receipt of the Nineteenth Annual Report of the Nebraska Agricultural Experiment Station.

JOHN H. MICKEY,
Governor.

THE OFFICIAL ROSTER OF THE STATION.

THE GOVERNING BOARD (THE REGENTS OF THE UNIVERSITY).

HON. CARL J. ERNST, Omaha, President	Term expires 1908
HON. ELISHA C. CALKINS, Kearney	Term expires 1908
HON. CHAS. S. ALLEN, Lincoln	Term expires 1910
HON. WILLIAM G. WHITMORE, Valley	Term expires 1910
HON. FREDERICK H. ABBOTT, Columbus	Term expires 1912
HON. VICTOR G. LYFORD, Falls City	Term expires 1912

J. S. DALES, Lincoln, Financial Secretary.[1]

THE EXECUTIVE COMMITTEE.

CARL J. ERNST E. BENJAMIN ANDREWS E. A. BURNETT

THE STATION OFFICERS.

E. A. BURNETT, B. SC.	Director and Animal Husbandman
T. L. LYON, PH. D.	Associate Director and Agriculturist
WILLIAM W. MARSHALL	Executive Clerk

THE WORKING STAFF.

H. R. SMITH, B. SC.	Animal Husbandman
A. T. PETERS, D. V. M.	Animal Pathologist
F D. HEALD, PH. D.	Botanist
S. AVERY, PH. D.	Chemist
A. L. HAECKER, B. SC. A.	Dairy Husbandman
LAWRENCE BRUNER, B. SC.	Entomologist
E. H. BARBOUR, PH. D.	Geologist
G. R. CHATBURN, A. M.	Highway Engineer
R. A. EMERSON, B SC.	Horticulturist
O. V. P. STOUT, C. E.	Irrigation and Drainage Engineer
G. D. SWEZEY, M. A.	Meteorologist
J. H. GAIN, M. D. C.	Associate Animal Pathologist
R. H. SHAW, B. SC.	Associate Chemist
ALVIN KEYSER, B. SC.	Asst. in Agr. and detailed from U. S. Dept. of Agr.
S. W. PERIN	Farm Foreman
W. P. SNYDER, M. S.	Supt. Experimental Substation, North Platte

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[1] By an act of the Legislature of the State of Nebraska approved and in effect February 15, 1899, the State Treasurer became *ex officio* custodian of the Experiment Station fund on and after July 1, 1899.

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University

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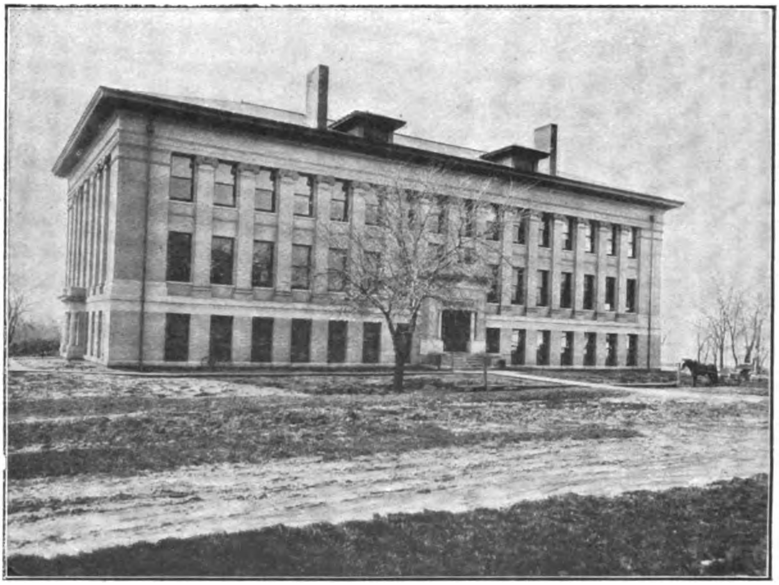

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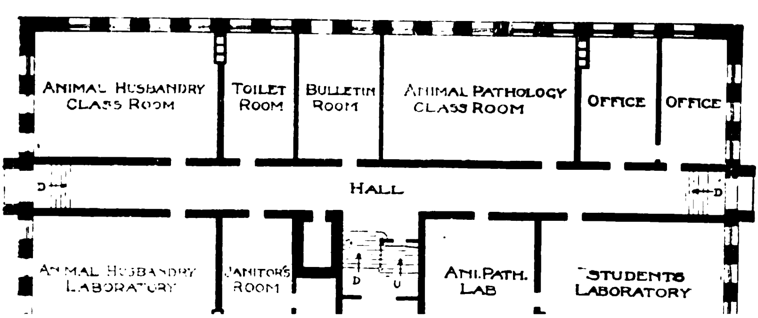

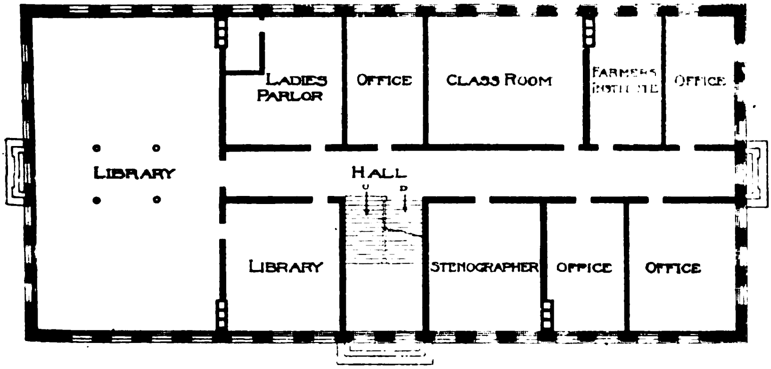

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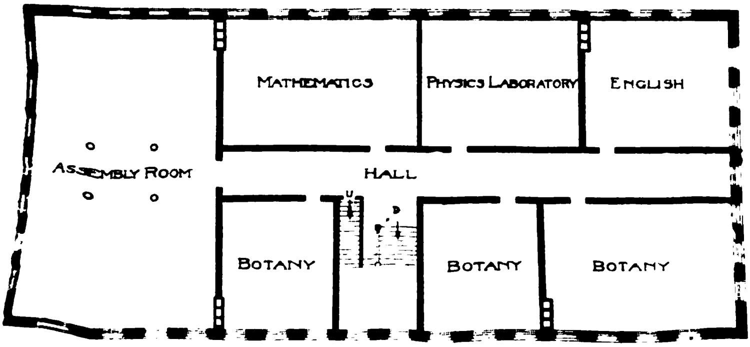

NINETEENTH ANNUAL REPORT.

EXPERIMENTAL WORK.

The work of the Experiment Station for the current year has been confined to the following lines, namely:

Improvement of winter wheat and oats, by (1) selection of desirable varieties, (2) crossbreeding varieties, and (3) selection of individual plants of desirable qualities.

Improvement of corn, by (1) selection of varieties, (2) selection of individual plants of desirable qualities, and (3) determination of varieties best adapted to several sections of the state.

Improvement of alfalfa by selection of individual plants of desirable qualities.

Selection of varieties of cowpeas and soy-beans.

Effect of manure, grass, and rotations on crop production.

Cattle feeding experiments to determine the relative efficiency of different rations, using snapped corn or shocked corn for grain, and prairie hay, alfalfa hay, or cornstalks for roughness, as follows:

Lot 1, snapped corn and prairie hay.
Lot 2, snapped corn, prairie hay, and alfalfa.
Lot 3, snapped corn and alfalfa hay.
Lot 4, snapped corn and cornstalks.
Lot 5, snapped corn, cornstalks, and alfalfa.
Lot 6, shock corn and alfalfa.

The effort in this experiment is to determine what sort of roughness is most economical to use in connection with snapped corn and to determine as far as possible the most economical method of producing beef during the first half of the feeding period.

Investigations are in progress also to determine the relative value of so-called supplemental protein foods during the second half of the fattening period, using wheat bran, linseed-meal, and cottonseed-meal in connection with corn, as follows:

Lot 1 receive shelled corn and prairie hay.

Lot 2 receive shelled corn, bran, and prairie hay.

Lot 3 receive shelled corn, linseed-meal, and prairie hay.

Lot 4 receive shelled corn, cottonseed-meal, and prairie hay.

Lot 5 receive shelled corn, alfalfa, and prairie hay.

Lot 6 receive corn and cob meal, alfalfa, and prairie hay.

Experiments are just completed to ascertain the value of fat substitutes in connection with separator milk in rearing calves; also experiments in rearing calves upon corn silage with grain.

Experiments are now in progress to determine the value of Blatchford's Calf Meal fed in connection with separator skim-milk in rearing calves.

A test is being made with dairy cows of the value of alfalfa and corn silage compared with alfalfa alone, mixed grains being used in both cases to complete the ration.

An experiment to determine the poisonous effect of the common horsetail weed *Equisetum arvense* was conducted at Valley, Nebr., by the Experiment Station, 205 pounds of *Equisetum* hay being eaten by one horse without fatal effect.

Investigations are in progress concerning the poisonous effects of three species of loco weed found in this state which is supposed to be very fatal to horses in certain localities.

Investigations are in progress to determine the nature and cause of cornstalk disease; also of a peculiar disease called "swamp fever," which has caused the death of many horses in the northern part of the state.

During the past year a special study has been made of "A Black Rot of Apples" and "The Trunk Rot of the Cottonwood." The final report on these two subjects is in preparation. In addition to this, a study of the plant diseases prevalent in the state has been begun and the appended report has been submitted to the Bureau of Plant Industry, Washington, D. C., giving the results of the work up to date.

The study of the noxious weeds of the state that has been carried on for some years in the Department of Botany has been continued. Some of the most prominent and important results of the weed studies are the confirmation of:

(a) The introduction and spread of noxious weeds by the use of impure seed. One of the striking examples is the spread of English Plantain by the use of impure alfalfa seed. Several weeds never before reported from the state have been obtained from alfalfa fields, these including one species that is new on this continent.

(b) The adulteration of alfalfa seed. The seeds used have not been those of noxious weeds, but generally those of other legumes of much less cost, and less value as forage plants. The plant most commonly reported from the alfalfa field is *Medicago lupulina*, or Hop Medic.

In the study of the plant diseases of the state a number of new or little known troubles have been discovered that are demanding further investigation. Among the more important may be mentioned the following:

(a) Twig Girdle of Apple, reported from Sheridan County (see Report, p. 26).

(b) Apple Leaf-spot (see Report, p. 23).

(c) Canker of the Plum (see Report, p. 32).

(d) Root Rot and Shot-hole of the Cherry (see Report, p. 28).

(e) Fruit Rot of the Tomato (see Report, p. 39).
(f) Bacterial Blight of the Soy Bean (see Report, p. 41).
(g) Kernel Mould of Kafir Corn (see Report, p. 44).
(h) Wheat Leaf Fungus (see Report, p. 46).
(i) Bud Rot of the Carnation and Chrysanthemum (see Report, pp. 55 and 57).

Experiments on the extermination of dandelions are in progress.

Investigations regarding varieties of garden vegetables have been completed during the past year; also investigations in the study of cover-crops for orchards.

Experiments in orchard culture to determine the effect of methods of cultivation and cropping upon growth have been continued for five years and partially reported in Bulletin 79. These experiments are to be continued in modified form.

Experiments in pruning orchards and also in spraying have been in progress for the past two years. The effect of spraying has generally shown a marked improvement of the fruit secured.

Experiments have been conducted with potatoes to determine the effect of mulching, of home-grown versus northern-grown seed, of thorough cultivation versus ordinary cultivation, and of large versus small seed pieces.

Work is in progress to produce a hardy apple of long-keeping quality for Nebraska.

An effort is also being made to secure a hardy drought-resisting variety of raspberry which will not winterkill.

COOPERATIVE EXPERIMENTS.

Cooperative experiments are in progress with about 500 farmers in determining the profitable limits of winter wheat production in the state.

Two hundred and fifty persons in the state are testing Kherson oats.

One hundred and twelve persons are testing 20 varieties of corn, mostly in eastern and central Nebraska.

Three hundred and fifty persons are testing macaroni wheat in western Nebraska.

Extensive cooperative tests with *Bromus inermis* are also in progress.

Cooperative experiments are in progress to determine the cost of spraying commercial orchards and the profit from such treatment.

Experiments are under way with the United States Department of Agriculture in the improvement of hard winter wheat and in the adaptation of numerous crops in the state; also in the prosecution of the plant disease survey of the state and in testing varieties of vegetables.

STATION STAFF.

In the Department of Chemistry, Dr. Samuel Avery has been placed in charge of the Chemical Department of the University, retaining general direction of chemical investigations in the Experiment Station.

Mr. Alvin Keyser has been transferred from Assistant in Chemistry to Assistant in Agriculture.

Mr. Roscoe H. Shaw has been elected Associate Chemist, since January, 1906, coming to us from the Kansas Agricultural College.

Since the organization of the Station, Dr. Charles E. Bessey has been Station Botanist, in recent years acting mainly as consulting botanist although some investigation has been carried on. In July, 1905, Dr. Frederick D. Heald was elected Station Botanist and means were provided by which the Department can undertake active investigation.

IMPROVEMENTS.

During the current year some improvements have been made to the beef cattle barn, including the construction of a silo. Agricultural Hall was completed, at a cost of $65,000, and contracts have been let for the completion of a permanent sewer to the agricultural plant.

THE SUBSTATION AT NORTH PLATTE.

Experimental work on the Substation farm has been much hampered by a lack of buildings and facilities for experimental work, and considerable effort has been directed to making improvements which will provide better conditions in the future.

During the present year a residence has been completed for the Superintendent, at a cost of about $3,500, a horse barn has been erected, and a foreman's house has been remodeled and moved to the central location. Sheds have been built to house 175 head of cattle and corrals in which experimental work can be done. Sheds have been built for about 200 hogs used in experimental work. About two miles of woven wire fence has been built to make possible the experiments in pasturing alfalfa with hogs, which is to be a leading feature of the Substation work. Something more than $8,000 has been expended in these various improvements.

The work taken up at the Substation has been so arranged as not to duplicate the work which can be done at the central Station. All of the more technical work which demands laboratories is undertaken at the central plant and not at the Substation.

Extensive tests are being made in growing forage crops and tame grasses, especial attention being given to the growing of alfalfa, brome grass, meadow fescue, and other grasses, and to the growing of Indian corn, sorghum, Kafir corn, and Jerusalem corn, and other forage crops of this nature.

Rather extensive experiments have been undertaken to test varieties of such grains as durum wheats, emmer, barley, Kherson and Sixty-day oats, and other varieties of oats, in an effort to determine what small grains are adapted to central Nebraska.

Tillage experiments have been undertaken to determine the effect of deep and shallow cultivation and of frequent cultivation in comparison with ordinary methods, using potatoes, corn, and other cultivated crops for this purpose.

Experiments are in progress to determine methods of wintering live stock most economically. In this experiment 100 calves are being used, divided in five lots, each lot securing two pounds of grain per day, two-thirds corn and one-third oats.

Lot 1 receives alfalfa hay.
Lot 2 receives prairie hay.
Lot 3 receives sorghum hay.
Lot 4 receives alfalfa and sorghum.
Lot 5 receives alfalfa and prairie hay.

Experiments are in progress to determine the relative feeding value of corn as compared with emmer or with barley; also as compared with corn when five per cent tankage is fed.

Experiments are also in progress to determine what percentage of grain to live weight furnishes the most economic production with hogs upon alfalfa pasture.

Arrangements are in progress for experiments in cooperation with the United States Department of Agriculture: (a) with the United States Forest Service in planting and growing timber; (b) with the Bureau of Plant Industry in cultivation methods.

Much attention will be given to the methods of cultivation necessary to secure stands of alfalfa and grass for meadow and tame pastures and to the question of improving the native pastures of the country by different methods of treatment. The attention of the Station will be largely directed to the relative productiveness of lands which have been for some time under crop and those on which humus has been recently applied either as barnyard manure or by plowing under sod. To determine the effects of humus upon the productiveness of the soil, rotation experiments will be carried on.

FARMERS' INSTITUTES.

Several members of the Experiment Station staff have assisted in Farmers' Institute work during the year. One hundred and fifty Institutes were held during the year closing June 30, 1905, and about an equal number will be held during the current year. Six thousand dollars per year is appropriated from the general fund of the state for this extension work.

Various agricultural societies meet with the University each year, including the State Board of Agriculture, the State Horticultural Society, the State Dairymen's Association, the State Live Stock Breeders' Association, the State Swine Breeders' Association, the State Veterinary Medical Association, the State Poultry Association, the Duroc-Jersey Swine Breeders' Association. The American Breeders' Association also met this year with the allied societies. About 2,000 people were in attendance.

PUBLICATIONS.

To accommodate the mailing lists, bulletins have been published during the last year in from 30,000 to 40,000 editions. The Annual Report, containing the financial statement and resume of the experimental work of the Station, was published in an edition of 5,000 copies.

The publications of the Station since those named in the last Annual Report are as follows:

Eighteenth Annual Report. Presented to the Governor February 1, 1905. 5,000 copies.

Bulletin No. 87 (Vol. XVII, Art. III). A Test of Calf

Bulletin No. 88 (Vol. XVII, Art. IV). Apple Scab and Cedar Rust. By R. A. Emerson. Distributed May 9, 1905. 24,000 copies.

Bulletin No. 89 (Vol. XVII, Art. V). Winter Wheat. (Cooperative Experiments with the United States Department of Agriculture.) By T. L. Lyon and Alvin Keyser. Distributed June, 1905. 40,000 copies.

Bulletin No. 90 (Vol. XVIII, Art. I). Cattle Feeding Experiment. By H. R. Smith. Distributed November 25, 1905. 35,000 copies.

Bulletin No. 91 (Vol. XVIII, Art. II). Experiments with Corn. By T. L. Lyon. Distributed December 5, 1905. 30,000 copies.

ACKNOWLEDGMENTS.

The various railroads of the state have furnished considerable transportation to assist in carrying on experimental work located outside of Lincoln.

The agricultural press, especially those papers located within the state, have shown their appreciation of the work of the Experiment Station by giving a liberal amount of space to the experimental work reported and in every way facilitating and extending the usefulness of the Experiment Station.

THE UNIVERSITY OF NEBRASKA
Secretary's Office.

The Agricultural Experiment Station of Nebraska
In account with
The United States appropriation, 1904-5.

RECEIPTS		
Received by the state treasurer from the treas- of the United States, installments for the r ended June 30, 1905, under the act of gress approved March 2, 1887	$15,000 00	
EXPENDITURES.		
salaries		$ 8,800 71
labor		1,695 53
publications		1,508 82
postage and stationery		602 97
freight and express		97 20
chemical supplies		134 09
seeds, plants, and sundry supplies		455 25
feeding stuffs		633 92
tools, implements and machinery		235 99
furniture and fixtures		92 15
scientific apparatus		267 19
live stock		397 60
traveling expenses		30 63
contingent expenses		15 00
buildings and repairs		32 95
	$15,000 00	$15,000 00

SUPPLEMENTARY STATEMENT.

RECEIPTS.		
State treasury receipts from other sources than the United States for the year ended July 31, 1905: balance July 31, 1904	$ 655 98	
Sales of stock, produce, etc	7,679 47	
EXPENDITURES.		
For salaries		$ 1,238 91
labor		717 26
publications		10 25
postage and stationery		144 97
freight and express		219 01
seeds, plants and sundries		518 29
feeding stuffs		1,962 50
tools, implements and machinery		345 46
furniture and fixtures		10 80
scientific apparatus		271 15
live stock		586 05
traveling expenses		17 30
building and repairs		
Balance, July 31, 1905		1,
	$ 8,335 45	$ 8,

Lincoln, Nebr., Dec. 30, 1905.

J. S. DALES,
Financial Secretary.

FARMERS' INSTITUTES.

Legislative appropriation of (April) 1905 from state general fund (2 years)	$12,000 00
EXPENDITURES.	
To November 30, 1905, for	
Superintendence, clerical service, lecturer's expenses and services, printing, supplies	375 13
Balance	$11,624 87

SUBSTATION (NORTH PLATTE).

Legislative appropriation of (April) 1905 from state general fund (2 years)	$12,000 00
EXPENDITURES.	
To November 30, 1905, for	
Superintendence, labor, live stock, feed, seed, tools, machinery, permanent improvements and supplies	$ 7,658 31
Balance	$12,341 69

REPORT ON THE PLANT DISEASES PREVALENT IN NEBRASKA DURING THE SEASON OF 1905

By Frederick De Forest Heald, Ph. D.

BOTANIST OF THE EXPERIMENT STATION AND COLLABORATOR IN THE BUREAU OF PLANT INDUSTRY, WASHINGTON, D. C.

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I. TREE FRUITS.

APPLE, *Malus malus* (L.) Britton.

BLACKHEART, *Bacillus*(?).—Reported from Lancaster, Saline and Platte Counties. Extent of injury not indicated.

BLACK-ROT, *Sphacropsis malorum* Pk.—Reported from Holt County. Abundant in Lancaster County on immature apples in the orchard and at maturity. Also common on apples in storage. (2)[1]

BROWN-ROT, *Sclerotinia fructigena* (Pers.) Schrt.—For the last few years a peculiar black-rot of apples has been observed that has proved on careful study to be due to the Monilia stage of the above fungus. Apples either on the tree or in storage are transformed into blackened mummies that shrivel only slightly and are apparently exempt from the attacks of other organisms. Sclerotinia has been repeatedly isolated in pure culture from these black apples and inoculations have been successful. The apples have somewhat the appearance of the apples affected with true black-rot, but the epidermis remains smooth and is a shiny coal black. The mycelium is confined entirely to the pulp of the apple and does not break through the epidermis to form conidial tufts as in the typical brown rot of peaches, cherries, and plums. During the present year specimens have been received from Butler, Cass, and Lancaster Counties. (See p. 82 of this Report.) (3)

CROWN-GALL, ?*Dendrophagus globosus* Toumey.—Reported only from nursery stock in Saline and Scotts Bluff Counties. (4)

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[1] The numbers in parentheses after each disease mentioned refer to corresponding numbers in the appendix to this report, where suggestions are given for the prevention and treatment of the most important diseases. See p. 60.

FIRE-BLIGHT, *Bacterium amylovorum* (Burr.) Chest.—Fire-blight has been common throughout southeastern part of the state and in southern Iowa. In southern Iowa in certain localities, nearly every tree was affected, many having fully half of the foliage killed. It has also been reported from other parts of this state: Holt County, loss 10 per cent; Furnas County. The correspondent from Furnas County states that almost entire orchards have been lost by neglecting to keep the blight in check by the use of knife and fire. A loss of 30 car-loads is the estimate reported from Johnson, Nemaha County. One correspondent reports Maiden's Blush the most susceptible, and Tetofsky and Whitney the most resistant. (5)

FLY-SPECK FUNGUS, *Leptothyrium pomi* (Mont. and Fr.) Sacc.—Quite common in orchards that are not sprayed. Rare in the orchards sprayed for scab. (6)

GREEN MOULD, *Penicillium glaucum* Lk.—This fungus is the most common cause of the rotting of apples in storage. It is present throughout the entire state. The mould spreads readily from apple to apple in the bin, but spores are not produced very abundantly unless the apples are kept in very damp places. The transformation of the apple into a soft brown pulp is often the only external indication of the fungus. In old apples in damp chambers the Coremium stage of the fungus frequently appears. By cultures on various artificial media, *Coremium glaucum* and *Penicillium glaucum* have been shown to be the same fungus. (By G. L. Fawcett in Pathology Lab.) (15)

LEAF-SPOT, *Phyllosticta* sps.—Leaf-spot has been very abundant in Lancaster County and Washington County. In both cases the variety most seriously affected is the Ben Davis. What appeared to be the same trouble was reported from Scotts Bluff County. The disease does not appear at all in the early part of the season and consequently does not seem to be affected by the early spraying for scab. Later sprayings appear to lessen the amount of the disease to a slight extent. The harmful result of the disease is the premature defoliation which it causes. In one large orchard visited, the Ben Davis trees were entirely defoliated while the other varieties retained nearly their normal foliage. In only a few cases was the fungus found in fruit on the leaves while still on the tree. Leaves placed in damp chambers produced the fruit dots in abundance. (9)

PINK MOULD, *Cephalothecium roseum* Cda.—The apple rot caused by this fungus has been observed on imported varieties in the market (Greenings) and on seedlings from Grand Island. (15)

POWDERY MILDEW, *Podosphaera leucotricha* (Ell. and Ev.) Salm.—Not common this year as only a single report has been received.

RUST, *Gymnosporangium macropus* Lk.—The cluster-cup stage of this species is common throughout the eastern half of the state. No reports of its presence have been received from points west of Custer County. This species has been noted at Lincoln on the wild crab, *Malus iocnsis*. In spite of the publication of Bulletin 88, "Apple Scab and Cedar Rust," no reports of treatment have been received. Rust does not seem to have been a serious pest of apple orchards during the past year, although it has been fairly common. Wealthy is mentioned as one variety most affected, while the Winesap is quite exempt. (See also Bull. 88, Nebr. Exp. Station.) Up to date no reports of the presence of *G. globosum* in the state have been received. (12)

SCAB, *Venturia inaequalis* (Cke.) Aderh.—Scab has continued to be one of the most serious apple troubles of the state. The majority of apples in the market are damaged 30–50 per cent. The great per cent of the injury has been from the scabby fruit, but two different conditions of the fungus have been observed on the leaves. During the early part of June an orchard was visited that contained numerous trees that were dropping their leaves to a considerable extent. Before the leaves were cast, they turned yellow and many of the leaves not yet cast were more or less variegated with yellow, brown and green. On the isolated green spots the scab fungus was always found, the affected spots then showing a conservation of the chlorophyll. The typical scab colonies on the leaves were not uncommon. Later in the season the scab spots showed in many cases a considerable hypertrophy of the leaf tissue, with frequently a dead area in the center that often drops out leaving an irregular perforation. One correspondent reports Winesap, Walbridge, and Genet very scabby, only 50 per cent marketable. The Winesap is reported most susceptible and the Ben Davis the most resistant. In all cases where spraying is practiced, correspondents report that scab is controlled by Bordeaux mixture. Power sprayers are used in two orchards, but spraying by any process is by no means general.

The following results are given by Professor R. A. Emerson of cooperative spraying experiments in the orchard of G. A. Marshall, Arlington, Nebr. Scab and leaf-spot were the diseases present, and Bordeaux mixture was the fungicide used:

Variety.	ROW	Treatment.	Crop.	Amt. of Scab.	Condition of foliage Sept. 30.
Genet	23	Sprayed May 1 Sprayed May 26	40 %	Almost free ..	Good
Genet	21	Sprayed May 1	5 %	More scab than in row 23 ...	½ fallen
Sheriff.....	23	Sprayed May 1 Sprayed May 26	10 %	Fairly free....	Fair
Sheriff......	21	Sprayed May 1	None	....	90 per cent fallen
Ben Davis..	18	Sprayed May 26	5 %	Almost free....	75 per cent fallen
Ben Davis..	20	Not sprayed	2 %	Alm'st w'rthless	95 per cent fallen

The spraying seems to have slightly lessened the premature defoliation from leaf-spot. (13)

SOOTY BLOTCH, *Phyllachora pomigena* (Schw.) Sacc.—Same as for Fly-speck Fungus. (16)

TRUNK-ROT, *Irpex sinuosus* Fr.—In one orchard (Lincoln) this fungus was found quite abundant and there seemed to be no doubt that it was really parasitic. At the time observed the trees affected were still living but they were very rapidly succumbing to the attacks of this fungus which apparently entered through large wounds made by improper pruning. (17)

TWIG-GIRDLE, *?Phoma.*—A new disease of the apple called twig-girdle has been reported from Sheridan County. According to the correspondent, "The upper and side limbs seem to die. Some trees fifteen years old have whole tops dead, only body and few of the largest limbs alive. Others have lost only a small percentage." The young twigs are completely girdled at successive points, the portion distal to the lowest girdle being dead. The fungus grows just under the epidermis, in the form of brownish filaments or irregular aggregates of cells, but no spore formation has been observed. The epidermis is slightly raised in places by the growth of the fungus, thus producing silvery patches. The fungus has also been found on the living portion just below the lowest girdle. (18)

FREEZING.—Apples suffered to some extent from the severe winter and from the late frosts. Correspondent from Burge, Cherry County, reports: "Most of our crop of apples and cherries was caught by frost this spring." The

Record for November, December, January, and February, 1887-1905.

WINTER OF	1887-1888	1888-1889	1889-1890	1890-1891	1891-1892	1892-1893	1893-1894	1894-1895	1895-1896	1896-1897	1897-1898	1898-1899	1899-1900	1900-1901	1901-1902	1902-1903	1903-1904	1904-1905
Lowest ° Temp	-27	-17	-16	-12	-29	-17	-19	-18	-5	-10	-18	-26	-12	-4	-13	-13	-14	-26
No. of -0° Days ...	25	10	14	5	9	16	10	16	2	10	6	25	8	3	16	8	12	24
Total -0° Degrees ..	-258	-56	-128	-37	-121	-100	-65	-127	-9	-46	-37	-231	-52	-8	-114	-52	-58	-278

In the period covered by the above table, the winters of 1887–88, 1898–99, and 1904–5 may be noted as especially severe.

The distribution of the zero temperatures for the three cold years may be compared in the following tables: (7)

1887–1888	No. of zero days	Sum of -0 degrees	Mean of Min. Tem.	1898-1899	No. of zero days	Sum of -0 degrees	Mean of Min. Tem.	1904–1905	No. of zero days	Sum of -0 degrees	Mean of Min. Tem.
Nov., 1887	3	-19	....	Nov., 1898	2	-3	23.7	Nov., 1904	0	0	32.2
Dec., 1887	5	-49	....	Dec., 1898	4	-14	14.5	Dec., 1904	2	-6	17.2
Jan., 1888	14	-168	....	Jan., 1899	5	-43	15.2	Jan., 1905	8	-82	6.1
Feb., 1888	3	-22	....	Feb., 1899	14	-171	3.5	Feb., 1905	14	-190	6.1
Total..	25	-258	....	Total..	25	231	56.9	Total..	24	-278	61.6
				Mean Min. for 4 Mos.			14.2	Mean Min. for 4 Mos.			15.4

APRICOT, *Prunus armenicola* L.

FIRE-BLIGHT, *Bacterium amylovorum* (Burrill) Chest.—A single case of fire-blight has been reported from Furnas County on the Russian apricot. (5)

CHERRY, *Prunus* Sp.

BLACK-KNOT, *Plowrightia morbosa* (Schw.) Sacc.—Black-knot has been reported on the cherry from only a single locality in Platte County. (See also Plum.)

BROWN-ROT, *Sclerotinia fructigena* (Pers.) Schrt.—No reports of the brown-rot on the cherry have been received outside of Lancaster County, but it has undoubtedly been present. Here it has only been observed on the fruit.

GUMMOSIS.—Gummosis is reported as common in orchards in Sarpy County. Correspondent says: "Nearly every tree is covered with gum, softer than usual. Over the trunk pieces coagulate as large as a man's thumb. Ninety per cent more than last year."

POWDERY MILDEW, *Podosphaera oxycanthae* (DC.) DeBy.—Reported from Platte, Saline and Lancaster Counties. Very common in Lancaster County on the Sand Cherry (*Prunus besseyi* Bailey). No treatments.

ROOT-ROT.—Root-rot due apparently to a basidiomycetous fungus has been observed as quite general in one large orchard in Lancaster County. Many trees have been killed by the combined effect of the root-rot and the shot-hole. Much of the trouble with cherry trees attributed to the shot-hole fungus is probably caused by this disease. The trees grafted on Mahaleb roots seem to be much more susceptible to the disease. In one orchard visited, the majority of the trees on Mahaleb roots were either dead or barely alive, while most of those on their own roots were in good condition. In many cases before the tree was dead the root and base of trunk were so weakened by the inroads of the fungus that it was blown over. An examination of the wood of root and lower part of the trunk in such cases shows it to be thoroughly pervaded by the mycelium of a fungus.

RUST, *Puccinia pruni* Pers.—Cherry rust has been reported from Saline and Lancaster Counties. At the State Farm it has only been found on *P. serotina*.

SHOT-HOLE, *Cylindrosporium padi* Karst.—Cherry shot-hole has been common throughout the eastern half of the state. *P. besseyi*, the Sand Cherry, appears to be quite resistant. Of the varieties from *Prunus cerasus*, the Early Richmond is uniformly reported as the most resistant, while the English Morello and other late varieties are particularly susceptible. Shot-hole has been very severe on

P. serotina at Lincoln. The time of first appearance of the disease varies in different reports from the early part of May to as late as July 1 (Holt County). The per cent of crop injured is estimated from 20-40 per cent, but this low percentage of loss is explained by the fact that many report the English Morello trees the susceptible variety already killed. Whether this has been due to the shot-hole alone is a point that remains as yet unsolved. (See Root-rot.)

In a few cases cherries have been sprayed with Bordeaux, but spraying has not been generally practiced. One orchardist[1] reports as follows: "Our cherry orchard was sprayed four times: the *first* time before the buds opened; the *second,* before the fruit emerged from the sheath. The *third* spraying was when the fruit was half grown, and the *fourth* after the fruit was picked." The Early Richmond did not shed its foliage until the 15th of November, and the large Montmorency not until later or about November 19th. The trees were in a very healthy condition and there was no indication of shot-hole. (14)

TRUNK-ROT, *Schizophyllum commune* Fr.—This fungus is generally considered as a saprophyte, but a case of undoubted parasitism has been reported from a small cherry orchard in Lincoln. The orchard affected was not an old one, but consisted entirely of young trees five and six years old. The external symptoms of the disease were not noticed till June, when the sporophores began to appear on the limbs and trunks as minute whitish specks. By the first of November the sporophores were well developed, and were abundant on trunks and on the branches. At the time examined the trees were still alive with sporophores growing on limbs that were still alive. The wood was thoroughly permeated by the mycelium of the fungus, rendering it very brittle, and the characteristic black lines produced by wood-rotting fungi were quite noticeable.

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[1] E. F. Stephens, Crete, Nebr.

During the early part of the season the trees showed symptoms of a weakened condition, but the cause was not understood until the sporophores began to appear. In the entire orchard not a single tree is exempt. The orchard has been under cultivation, being planted to garden vegetables. The indications are that the fungus gained an entrance through the roots which were injured by the very close cultivation. (17)

PEACH, *Prunus persica.*

BROWN-ROT, *Sclerotinia fructigena* (Pers.) Schrt.—Reported only from Lancaster County. Not present in any extent owing to the almost complete failure of the peach crop. (See Winter Injury.) (3)

CROWN-GALL, *Dendrophagus globosus* Toum.—Reported only from Saline County. (4)

LEAF-CURL, *Exoascus deformans* (Berk.) Fckl.—Leaf-curl is reported from the eastern half of the state, but in no case is the injury estimated at over 29 per cent. In Nemaha County a very great increase is noted. No treatment reported. (8)

POWDERY MILDEW, *Sphaerotheca pannosa* (Wallr.) Lev.—Rare. Reported only from Johnson County. (11)

ROOT-ROT.—Reported from Furnas County. Extent and definite character of the disease not indicated.

SHOT-HOLE, *Cercospora circumcissa* Sacc.—Observed only in Lancaster County, but not common, or very injurious.

WINTER INJURY.—The unusually severe winter of 1904–5 killed nearly all the fruit buds, so that the peach crop for the state was a complete failure this year. Only in a few cases did the trees blossom. The freeze was so severe that many of the young shoots and even older ery and are in a very healthy condition at present. (See Apple, Winter Injury, for temperatures.) (7)

PEAR, *Pyrus communis.*

FIRE-BLIGHT, *Bacterium amylovorum* (Burr.) Chest.—Only a few reports of fire-blight on the pear have been received (Saline and Johnson Counties). This is probably due to the fact that the pear is not grown as extensively as the other tree-fruits in Nebraska, for blight has been common in the state. (See Apple.) (5)

LEAF-BLIGHT, *Entomosporium maculatum* Lev.—Reported only from Saline County, but not doing serious damage. (9)

PLUM, *Prunus* sps.

BLACK-KNOT, *Plowrightia morbosa* (Schw.) Sacc.—Reported from Platte and Lancaster Counties. Not very common. No injury reported by this alone. One orchardist estimates 25 per cent of crop destroyed by black-knot and plum-pockets. (1)

BROWN-ROT, *Sclerotinia fructigena* (Pers.) Schrt.—Brown-rot of the plum has been quite general in eastern Nebraska, but the reports received have been rather few, not indicating its real abundance. Estimates of injury reach as high as 40 per cent. No treatment reported. (3)

FIRE-BLIGHT, *Bacterium amylovorum* (Burr.) Chest.—What appears to be fire-blight has been reported from Furnas County on the following varieties: Burbank, Gold, and Wildgoose plums. (5)

PLUM-POCKETS, *Exoascus pruni* Fckl.—This disease is not uncommon in eastern and southern Nebraska. In a few cases whole trees have become infested by failure to prune the affected branches. The actual per cent of injury is small. (10)

SHOT-HOLE, *Cylindrosporium padi* Karst.—While the shot-hole fungus has not been as common on the plum as on the cherry, it is reported from three widely separated stations in southern part of state: Dundy Co., Furnas Co., and Howard Co. Correspondent from Dundy County reports one-half of the crop injured, and no treatment, except to mulch and enrich the ground. In none of the specimens examined was the shot-hole effect produced. (14)

SILVER-TWIG, *Phoma?*—A new disease reported from Howard County on Japanese plum (var. ?). The young twigs are slightly enlarged by the tumid cortex. The fruit spurs are more or less atrophied and shortened and a poor leaf development results. The fungus is generally distributed over the affected portion, being located beneath the epidermis in the superficial part of the cortex. By the growth of the fungus the epidermis has been lifted in irregular patches, producing a silvery color to the affected portions. On the material received Sept. 11, only the immature pycnidia could be found. The affected cells were pervaded by dark brown hyphae or filled with irregular aggregates of brownish cells. According to report this disease was not present last year. All of the trees are affected, but the extent of the injury can not be determined until further observations have been made.

TWIG-CANKER, *Bacterium?*—A new disease of the plum, apparently of bacterial origin, has been reported from Julian, Nemaha County. The first external indication of the disease on the twigs and branches is the somewhat swollen irregular longitudinal ridges of the cortex. An examination of these swollen areas in transverse section shows numerous radial rifts in the cortex which extend outwards to just below the epidermis. When the swollen area becomes sufficiently tumid some of these radial rifts extend outwards through the epidermis and open longitudinal slits are produced. The relief of the transverse tension in this region causes the cortex to gap open, and with the continued destruction of tissue and the growth of the twig, a canker spot of some size is formed. In the radial rifts before the canker was formed an abundance of non-motile rod bacteria were present. The few cultures tried up to date have not been successful. The entire absence of any filamentous fungi, even in the open cankers studied, leaves the bacterial cause of the disease as highly probable. The disease has been observed only on two varieties: the Wickson and the Whitaker.

II. SMALL FRUITS.

BLACKBERRY, *Rubus villosus* and var.

CROWN-GALL, *Dendrophagus globosus* Toumey.—Not as common on this host as on raspberry. Observed only at Lincoln. (4)

LEAF-SPOT, *Septoria rubi* Westd.—Common in Lancaster County, but not especially injurious. Also on uncultivated species. (22)

CURRANT, *Ribes rubrum.*

LEAF-SPOT, *Septoria ribis* Desm.—This disease is not uncommon in eastern Nebraska. It occurs also on the wild species of Ribes. It has been observed more abundant in Lancaster County than elsewhere. (22)

POWDERY MILDEW, *Sphaerotheca mors-uvae* (Schw.) B. and C.—Reported only from a single locality, Hamilton County. (25)

RUST, *Puccinia ribis* DC.—Reported only from Keith County. Its abundance was not indicated.

GOOSEBERRY, *Ribes* sps.

LEAF-SPOT, *Septoria ribis* Desm.—Same as for Currant.

POWDERY MILDEW, *Sphaerotheca mors-uvae* (Schw.) B. and C.—Reported from only a single locality in Knox County. (25)

RUST, *Puccinia ribis* DC.—Reported from York and Platte Counties. Not very abundant or destructive.

GRAPE, *Vitis* sps.

BLACK-ROT, *Guignardia bidwellii* (Ell.) Viala and Rav. —Black-rot has been reported from only a single locality in the southeastern part of the state (Nemaha County). (20)

DOWNY MILDEW, *Plasmopara viticola* (B. and C.) Berl. and De Ton.—Downy mildew has been much more abundant this year than last, according to observations and reports. It is not uncommon in the entire eastern half of the state. Specimens have been received from Knox, Otoe, and Lancaster Counties. One correspondent states that the disease was checked by spraying twice with Bordeaux mixture. At the Experiment Station, where the disease was not treated, the Big Hope, Beacon, Manito, and American varieties were only slightly affected. All other varieties were very severely attacked, scarcely a leaf being exempt. (21)

RASPBERRY, *Rubus* sps.

CANE-BLIGHT, *Sphaerella rubina* Pk.—This cane-blight has only been observed at Lincoln on the red raspberry. In some cases apparently about one-third of the canes have been killed by this fungus. It was not observed in the early part of the season.

CROWN-GALL, *Dendrophagus globosus* Toum.—This disease has only been observed at Lincoln, but without doubt occurs in other parts of the state. It has been quite abundant at the Station during the past three years, but the writer has not observed any appreciable injurious effect. Its infectious character has been corroborated by inoculation experiments carried out in the greenhouse. The inoculations were made in two ways: first, by placing a small piece of gall in an incision; second, by pouring minced galls on the soil around the base of the canes. In the first method large galls appeared at the points of inoculation; in the second, the galls were smaller and scattered over the root system. (4)

ANTHRACNOSE, *Gloeosporium venetum* Speg.—Reported only from eastern part of state: Platte, Lancaster, and Nemaha Counties. Black raspberry more affected than the red. Loss estimated at 2–20 per cent in different localities. (19)

STRAWBERRY, *Fragaria* sps.

LEAF-SPOT, *Sphaerella fragariae* (Tul.) Sacc.—Leaf-spot has been quite general in eastern Nebraska. Most of the reports come from the southeastern part of the state. Damage to crop is slight. One correspondent reports a successful treatment with Bordeaux. (23)

III. GARDEN VEGETABLES.

ASPARAGUS, *Asparagus officinalis.*

RUST, *Puccinia asparagi* DC.—Not uncommon in eastern part of state. *Darluca filum* seems to be constantly associated with the rust and there are indications that it is not entirely parasitic on the asparagus rust, as it is often found on portions of the stem from which the rust is largely absent. The rust has not been as serious as in former years, and no reports of the extent of injury have been received. (32)

LEOPARD SPOT. (Cause not determined.)—Reported only from Lincoln on the nearly mature stems. Disease is probably of fungus origin, but no spores have been found.

BEAN, *Phaseolus* sps.

BACTERIAL BLIGHT, *Pseudomonas phaseoli* Smith.—Reported only from a single locality: Dundy County. Estimated loss, 75 per cent of crop. Disease was not serious last year.

BACTERIAL SPOT. (?)—This disease has only been observed by the writer on Lima beans (*P. lunatus*) at Lincoln. It seems to be distinct from the preceding disease, but cultures and inoculation experiments have not been carried out. The disease is indicated by small reddish pustules $^1/_{16}$ to $^1/_4$ inch in diameter scattered over the surface of the affected leaf. The pustules are crowded full of motile rod bacteria. The disease seemed to be localized at these spots as otherwise the leaf appeared normal. The disease was not observed until late in the season (October).

ANTHRACNOSE, *Colletotrichum lindemuthianum* (Sacc. and Magn.) Bri. and Cav.—No reports have been received outside of Lancaster County, but the disease appears to be quite general at least in the eastern part of the state. Considerable damage is reported to market appearances of yellow-podded varieties such as Wardwell's, etc. (26)

RUST, *Uromyces appendiculatus* (Pers.) Lk.—Reported only from Lancaster County. Injury not indicated. Challenge and Black Wax are indicated as susceptible varieties, while Market Wax is mentioned as a resistant variety. (33)

BEET, *Beta vulgaris* and var.

LEAF-SPOT, *Cercospora beticola* Sacc.—This disease is common on beets in Nebraska, both in the garden and on sugar beets. The injury is very slight. (30)

SOFT-ROT, *Bacterium teutlium* Metc.—Reported on sugar beet from a single locality (Knox County). Extent of injury not indicated.

CABBAGE, *Brassica oleracea.*

BLACK-ROT, *Pseudomonas campestris* (Pam.) Smith.—What appears to be black-rot has been reported from four different counties in southern part of state: Dundy, Hitchcock, Hamilton, and Lancaster. Loss in different localities estimated from 20 to 100 per cent. The rot may prove to be distinct from the one under which it is placed as some of the symptoms deviate from those of the typical black-rot. No opportunity has been afforded for a detailed study of the disease. (28)

CELERY, *Apium graveolens*

LEAF-SPOT, *Cercospora apii* Fr.—Observed at Lincoln, and reported also from Beatrice. Correspondent reports the most rapid spread of disease during the month of August. After Sept. 1, a healthy growth was made. (30)

CUCUMBER, *Cucumis sativus.*

ANTHRACNOSE, *Colletotrichum lagenarium* (Pass.) Ell. and Hals.—Reported from Douglas and Lancaster Counties. Disease was first noticed the last of August. Very much more severe than last year. Loss due to this disease and wilt of both cucumbers and muskmelons is estimated at $10,000 to $15,000 for Douglas County alone. All varieties attacked. No treatment reported. (27)

WILT, *?Bacillus tracheiphilus* Smith.—Reported only from Douglas County. Occurring at same time as anthracnose, but not very abundant. See Anthracnose for loss. (36)

EGGPLANT, *Solanum melongena.*

FRUIT-ROT, *Phyllosticta hortorum* Speg.—Observed only at Lincoln. The disease was first noticed about Sept. 1, but in a few weeks 90 per cent of the crop was destroyed in the field under observation.

HORSERADISH, *Cochlearia armoracia.*

LEAF-SPOT, *Cercospora armoracia* Sacc.—This disease is reported from a single locality: Knox County. (30)

WHITE RUST, *Albugo candida* (Pers.) Ktze.—Lancaster County. Not very abundant. (35)

MUSKMELON, *Cucumis melo.*

ANTHRACNOSE, *Colletotrichum lagenarium* (Pass.) Ell. and Hals.—Reported from Colfax and Douglas Counties. See report for Cucumber for injury in Douglas County. Correspondent from Colfax County reports the first appearance of disease in June, and its rapid spread during month of July, while on August 15th all vines were dead. Loss 50–100 per cent. Melon lice were very abundant, and played a prominent part in causing the death of the vines. Only anthracnose was present on specimens sent for examination. (27)

ROOT-ROT. (See Squash.)

WILT, *Bacillus trdcheiphilus* Smith.—Same as for Cucumber.

OYSTER-PLANT, *Tragopogon porrifolius.*

POWDERY MILDEW, *?Erysiphe cichoracearum* DC.—Observed only at Lincoln, in one locality. First noticed on plants in August. Growth retarded at first, but later in season the plants recovered and did not appear to be materially injured. No perithecia were found. (31)

PEAS, *Pisum sativum.*

POWDERY MILDEW, *Erysiphe polygoni* DC.—Reported only from Lancaster County. First appearance was July 1st, hence no damage to early varieties; late varieties much injured. (31)

POTATO, *Solanum tuberosum.*

EARLY BLIGHT, *Alternaria solani* (E. and M.) J. and Gr.—Reported from four widely separated counties of the state: Howard, Boyd, Sheridan, and Scotts Bluff. This is the first report of this blight in the potato growing section of western Nebraska. Loss is estimated from 20 to 50 per cent. One correspondent reports the unsuccessful treatment with Bordeaux, but the spraying was not resorted to until the disease was well advanced. Early Ohio is mentioned as a particularly susceptible variety. (29)

Scab, *Oospora scabies* Thaxt.—Scab is not uncommon in the eastern half of the state. Some correspondents report it as more prevalent than last year. Per cent of crop injured is estimated as high as 50 per cent. No treatment is reported. (34)

Tip-burn, or **Leaf-scorch.**—Observed at Lincoln in early part of June. Also reported from Boyd County. The disease in both cases appeared during hot days that followed a rainy and cloudy period of some duration. The vines died before the tubers were matured, very materially lessening the size and yield.

Radish, *Raphanus sativus.*

Downy Mildew, *Peronospora parasitica* (Pers.) Tul.—Lincoln. Only a very few specimens observed.

White Rust, *Albugo candida* (Pers.) Ktze.—Observed only at Lincoln, but probably general in eastern half of state. (35)

Tomato, *Lycopersicum esculentum.*

Leaf Mosaic.—This physiological trouble was reported from a single location in Hitchcock County.

Leaf-spot, *Septoria lycopersici* Speg.—Reported from three widely separated counties in eastern half of state: Knox, Lancaster, and Hall. Extent of injury not indicated. (30)

Rot, (?).—A rot of the fruit has been quite common throughout the state. The loss is estimated at 10–50 per cent in different localities. The definite cause of the rot has not been determined, but it is evidently of fungus origin. The disease appears to be general except where vines are staked. The soft, thin-skinned varieties are reported as being particularly susceptible.

SQUASH, *Cucurbita* sp.

ROOT-ROT, (?).—A root-rot of squash and other Cucurbits is reported from Lancaster and Hitchcock Counties. No specimens were received. Correspondent from Trenton says, "Melon roots rotted off under ground when vines were nearly grown."

WILT, *Bacillus tracheiphilus* Smith.—Reported only from Bellevue, Sarpy County. Especially noticeable during month of August. Four-fifths of crop injured. (36)

WATERMELON, *Citrullus vulgaris.*

ANTHRACNOSE, *Colletotrichum lagenarium* (Pass.) Ell. and Hals.—Not very common. Reported from Lincoln, but probably present in other localities. (See Cucumber and Muskmelon.) (27)

WILT, *Bacillus tracheiphilus* Smith.—Same as for squash, but not causing as high a percentage of loss. (36)

IV. FORAGE CROPS.

A. LEGUMES.

ALFALFA, *Medicago sativa.*

DODDER, *Cuscuta epithymum* Murr.—Reported only from Boyd County where it is much more abundant than last year. Per cent of crop injured estimated at 10 per cent. Liming the soil is reported as doing a little good.

RED CLOVER, *Trifolium pratense.*

LEAF-SPOT, *Pseudopeziza trifolii* (Bernh.) Fckl.—Observed only at Lincoln. Not very common. (40)

RUST, *Uromyces trifolii* (A. and S.) Winter.—Observed only in Lancaster County, but probably distributed over the eastern section of the state. Only the uredo and teleuto spore stages have been observed.

SOY-BEAN, *Glycine hispida.*

BACTERIAL BLIGHT, *Bacillus* sp?—In this disease the leaves become covered with small brown spots or pustules. The spots increase in size and numbers and often become confluent. The spots are often surrounded by a narrow margin of yellow and finally all the intervening tissue becomes discolored and the leaf dies. Often large irregular patches of the dead tissue fall away, leaving perforations or irregular margins. Generally the tip of the leaf is the first part affected. The disease was not observed till early in October, so no cultural studies have yet been carried out. (37)

WHITE CLOVER, *Trifolium repens.*

BLACK-SPOT, *Phyllachora trifolii* (Pers.) Fckl.—Observed only at Lincoln. Not as common as last year.

B. GRASSES, WILD AND CULTIVATED.

CORD-GRASS, *Spartina cynosuroides.*

RUST, *Puccinia fraxinata* (LK.) Arthur.—Teleutospore stage only observed. Lincoln. (See also Ash.) Common.

BARNYARD GRASS, *Echinochloa crus-galli.*

SMUT, *Ustilago crus-galli* Tr. and Earle.—Observed only at Lincoln. Rare.

BIG CANDY GRASS, *Eragrostis major.*

SMUT, *Ustilago spermophora* B. and C.—Observed only at Lincoln. Rare.

BIG BLUESTEM, *Andropogon furcatus.*

RUST, *Puccinia andropogonis* Schw.—Common in vicinity of Lincoln.

BROME GRASS, *Bromus inermis.*

RUST, *Puccinia ?bromina* Erikss.—Observed only on isolated plants at Lincoln.

ERGOT, *Claviceps purpurea* (Fr.) Tul.—Reported from Webster County. Not common. (39)

FOX-TAIL, *Chaetochloa glauca.*

SMUT, *Ustilago panici-glauci* (Wallr.) Wint.—Not uncommon in vicinity of Lincoln.

MUHLENBERG'S GRASS, *Muhlenbergia racemosa.*

RUST, *Puccinia windsoriae* Schw.—Not uncommon in the environs of Lincoln.

RYE-GRASS, *Elymus canadensis.*

RUST, *Puccinia graminis* Pers.—Quite abundant in vicinity of Grand Island.

ERGOT, *Claviceps purpurea* (Fr.) Tul.—Very common, particularly along the Platte River and in eastern part of state. Correspondent from Grand Island reported that he had 1,000 tons of hay containing large amount of wheat- and rye-grass. Both were so badly infested with ergot as to render the hay worthless. (39)

SORGHUM. (See Cereals, etc.)

SWITCH-GRASS, *Panicum virgatum.*

RUST, *Uromyces graminicola* Burrill.—Common in vicinity of Lincoln. Teleutospore stage only specimens collected.

SCRIBNER'S PANICUM, *Panicum scribnerianum* Nash.

BLACK-SPOT, *Phyllachora graminis* (Pers.) Fuckel.—Lincoln. The specimens collected show mostly the ascigerous stage.

WHEAT-GRASS, *Agropyron occidentale.*

ERGOT, *Claviceps purpurea* (Fr.) Tul.—See Rye-grass.

CLADOSPORIUM, *Cladosporium herbarum* (Pers.) Link.—Common on specimens of wheat-grass from Grand Island.

V. CEREALS.

BARLEY, *Hordeum sativum.*

COVERED SMUT, *Ustilago hordei* (Pers.) Kell. and Sw.—Observed only at the Experiment Station on winter barley (Tennessee). Plat was badly infected. About 1-10 of the spikes were destroyed. Collected June 9, 1905. (46)

CORN, *Zea mays.*

CLADOSPORIUM, *Cladosporium herbarum* (Pers.) Link.—Common on leaves and husks of corn, but only appearing when the corn is approaching maturity. Damage slight if any to crop.

RUST, *Puccinia sorghi* (Schw.)—Very common in the vicinity of Lincoln. The writer has not seen a single corn field in this region that was not badly rusted. No reports were received of the occurrence of the rust in other parts of the state, but it was without doubt present in the eastern half. Does not appear to have materially injured the crop, as it does not become abundant until after the corn is well advanced in its growth.

SMUT, *Ustilago zeae* (Beckm.) Ung.—Smut of corn has been quite abundant in the state. It is even reported from the extreme northwest corner of Sioux County where little corn is grown. At the Experiment Station the smut balls have been observed on all parts of the plant: leaves, stems, ears, tassels, in considerable abundance. Loss is estimated from 1–2 per cent. Observer from Red Willow County reports, "Never saw so much before," while from Hitchcock County one-fourth as much as last year is indicated. (49)

KAFIR CORN, *Sorghum vulgare* var.

BACTERIAL BLIGHT, *Bacillus sorghi* Burr.—In the field observed scarcely a plant was exempt from attack. As another disease was present in the same field it is impossible to make any statement as to the extent of the injury. (41)

KERNEL-MOULD OR -BLIGHT, *Macrosporium* sp?—This disease was observed in a single field on the outskirts of Lincoln. The heads were completely blighted and it was only possible by quite diligent search to find a few perfect kernels. In the majority of cases the entire endosperm of the kernel had been destroyed by the fungus, leaving only the outer hull. In kernels not completely destroyed, the apex was generally somewhat hollowed out and the surface was overgrown with a dense tangle of the olive-colored fungus filaments. In the latter stage a microscopic examination showed many of the starch grains in the process of digestion, as the typical corrosion figures due to a diastatic enzyme were plainly discernible. Because of lack of facilities for the work the fungus has not been studied in cultures. The crop was a total loss.

OATS, *Avena sativa.*

FREEZING.—In the last part of April oats were reported frozen to the ground in some of the western counties of the state. Although in most cases a rapid recovery from the effect of the freezing was reported, the stand did not reach the normal, and the crop was somewhat lessened.

Rust, *Puccinia coronata* Cda.—Crown rust or red rust of oats. Specimens have been received from only Sheridan, Clay, and Lancaster Counties, but northern counties report some damage to crop by rust. No part of the state is exempt. Loss in some regions as high as 10 per cent. This species was very abundant at the Experiment Station on oats sowed late as an orchard cover-crop. (48)

Smut, *Ustilago avenae* (Pers.) Jens.—Loose Smut. Reports have been received from Boyd, Platte, and Hamilton Counties. Kherson oats at Experiment Station show a small per cent of smut. Estimates of loss from other counties reach as high as 50 per cent. (42)

RYE, *Secale cereale.*

Powdery Mildew, *Erysiphe graminis* DC.—Observed at the Experiment Station. Quite abundant, but not very injurious. (47)

Rust, *Puccinia graminis* Pers.—Not reported outside Lancaster County. (48)

SORGHUM, *Sorghum vulgare.*

Bacterial Blight, *Bacillus sorghi* Burr.—Apparently quite common in Lancaster County. Not reported from elsewhere. (41)

Head-smut, *Sphacelotheca reiliana* (Kuhn) Clint.—Reported only from the southwestern part of the state.

Kernel-smut, *Sphacelotheca sorghi* (Lk.) Clint.—Quite common on crop planted in low ground in vicinity of Lincoln. (45)

TEOSINTE, *Euchlaena mexicana.*

Rust, *Puccinia sorghi* Schw.—Observed on small plat cultivated at the Experiment Station. Spores mostly uredospores. (See Corn.)

WHEAT, *Triticum* sps.

BACTERIAL BLIGHT, *Bacillus* sp.?—A bacterial disease of wheat was observed in the breeding plat at the Experiment Station. The plants that were badly affected made only a stunted growth. The bacteria produced brownish streaks or spots, beginning at the tip of the leaf. Sometimes considerable red coloration also results. The spots increase in size until a considerable portion of the affected leaf is killed. Bacteria were constantly found in these areas, and pure cultures were obtained. Successful inoculations were made in young wheat plants in the greenhouse. From studies up to this time it is impossible to state whether the species is new or must be assigned to a previously described species.

LEAF FUNGUS, *Leptosphaeria tritici* Pass.—See Frank, pp. 302–3. Beginning in the last of May, reports were received from a considerable number of counties throughout the southern part of the state of a wheat disease that seems to correspond with Frank's description. Specimens examined from different sources showed mostly the *Septoria* and *Cladosporium* stages, but in a few cases some of the young perithecia were observed. The lower leaves were killed by this disease and in the early part of the season the whole field showed a pale color due to the attacks of this fungus. The disease does not seem to have caused a very great amount of loss. Correspondent from Buffalo County reports, "Heads about one-third shorter than normal, but otherwise good." This was from a field where the disease was known to be present. The shorter heads were apparently due to the lessened vigor of the plants as a result of the attacks. (44)

POWDERY MILDEW, *Erysiphe graminis* DC.—In the early part of the season powdery mildew was quite common on wheat at the Experiment Station. It was most abundant on plats that were growing very rank and thick. The fungus was present on the haulms as well as leaves and many of the lower leaves were killed by the attack. With the drier conditions that prevailed after the first of June the disease ceased to spread to any extent, and but little injury was due to the attacks. (47)

RUST, *P. graminis* Pers. and *P. rubigo-vera* (DC.) Wint. —Rust of wheat due principally to the stem rust and the leaf rust have been general throughout the state, but the abundance and consequent loss has been less than during last season. In a few localities there has been more rust: Sheridan County correspondent reports, "Three times as much as last year"; 2 per cent is reported from Cherry County, as against none (?) last year. The majority of estimates of loss from rusts do not exceed 10 per cent, but in one case (Sheridan County) the loss is reported as 50 per cent. The loss in regard to varieties in the last case is given as follows: bearded wheat 50 per cent; bluestem 25 per cent; macaroni 10 per cent. (48)

SCAB, *Fusarium culmorum* W. G. Smith.—Scab has been very rare, producing no loss. A very little has been observed at the Experiment Station, but its scarcity in comparison with former years is very striking. There is some inclination to attribute this disappearance of the disease to the severe winter temperatures that prevailed (see Apple Diseases). The ascospore stage seems to be rather uncommon and the extent to which the conidia spores are able to withstand freezing has not been determined.

SMUT, *Ustilago tritici* (Pers.) Jens.—Loose Smut. This species has been observed on Turkish Red at the Experiment Station, but only in small quantity. Also reported from Platte County, but with comparatively no loss. (43)

SMUT, *Tilletia foetans* (B. and C.) Trel.—Bunt or Stinking Smut. Specimens of this smut have been received from only one locality (Boyd County). Correspondent reports, "Where no vitriol was used, bluestem variety of wheat is very smutty, injuring price rather than yield." In the sample received all of the sound grains had the hair tuft (brush) at the extremity very conspicuously colored. This dark coloration was due to the abundance of the smut spores lodged in the tuft of hairs. In addition to the smut spores a few spores of a Helminthosporium were present. (42)

VI. FOREST AND ORNAMENTAL TREES AND SHRUBS.

ASH, *Fraxinus americana* and *lanceolata.*

RUST, *Puccinia fraxinata* (LK.) Arthur.—Observed only at Lincoln, but not as abundant as last year. (See Cord Grass.)

LEAF-SPOT, *Phyllosticta viridis* Ell. and Kell.—Very abundant at Lincoln, producing brown spots ¼ to ½ inch in diameter on the leaflets. The spots show a conspicuous yellow border on the upper surface; pycnidia show as minute black specks scattered over the entire under surface of the spots. In severe attacks a premature defoliation results, but the injury is slight. (50)

BLACK WALNUT, *Juglans nigra.*

LEAF-SPOT, *Marsonia juglandis* (Lib.) Sacc.—In this disease conspicuous brown spots ⅛ to ¼ inch in diameter are noticeable over the affected leaflets. As the disease advances the whole leaflet appears affected as it turns yellow and finally drops off. A very pronounced premature defoliation often results from the attacks of this fungus. On the under side of the brown spots the minute black spore-dots are arranged in concentric circles. (50)

BOX ELDER, *Acer negundo.*

SOOTY MOULD, *Dimerosporium pulchrum?*—Observed only at Lincoln, on a single tree. Upper surfaces of leaves were nearly covered with a dense growth of olive brown hyphae.

CATALPA, *Catalpa speciosa.*

POWDERY MILDEW, *Microsphaera elevata* Burr.—Observed only in the nursery at the Experiment Station. Not so abundant as last year. (51)

TRUNK-ROT, *Polyporus versicolor* (L.) Fr.—Lincoln. Not very abundant. (54)

CEDAR, *Juniperus virginiana.*

CEDAR-APPLES, *Gymnosporangium macropus* LK.—This disease of the cedar is very common in eastern part of the state and as far west as Custer County. No reports of the presence of "cedar-apples" or of apple-rust have been received from points farther west.[1] Nearly all observers report this disease on the increase. Correspondent from Valley County reports that the disease is 100 per cent worse than last year, with many trees killed during last two years. Trees 10–15 years old appear to be more susceptible than young trees. The only treatment employed has been pruning and picking of the apples, but this treatment is not effective in the more severe attacks. (See also Rust, under diseases of Apple.) (12)

COTTONWOOD, *Populus deltoides.*

TRUNK-ROT,[2] *Elfvingia megaloma* (Lév.) Murr.[3]—This fungus occurs as a facultative parasite in several localities. (Cass County.) The mycelium grows throughout the wood, and the lower portion of the trunk is often thoroughly pervaded before the sporophores make their appearance. Trees 30–40 years old seem to be more susceptible than younger ones. The lignin of the invaded wood is digested by the fungus, thus making the wood very brittle. The trunk may become so weakened that the tree is blown over by the strong winds. (54)

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[1] The writer has since observed the cedar-apples abundantly on cedar trees used for a windbreak around a young orchard, at Wilsonville, Furnas County. No rust was present on the apple trees.

[2] A Disease of the Cottonwood, paper read before the Nebraska Acad. Sciences, Jan., 1905. See this report, p. 92.

[3] Fomes applanatus (P.) Wallr.

A rot which is probably distinct from the above is reported from Dundy County. Correspondent says, "After three years' growth the trees did not leave out as they had done and decay commenced, and they began to die and break down close to the ground."

RUST, *Melampsora populina* (Jacq.) Wint.—Cottonwood rust has been very common in the vicinity of Lincoln. Specimens have also been received from Knox and Howard Counties. In none of the reports has the disease been noted as especially injurious. (52)

DOGWOOD, *Cornus stolonifera.*

LEAF-SPOT. (Fungus not determined.)—The lower leaves of the plant were covered with conspicuous brown spots. The dead areas fall out, producing a very marked shot-hole effect. In some cases over half of the leaf tissue is lost in this way.

ELM, *Ulmus americana.*

BLACK-SPOT, *Dothidella ulmi* (Duv.).—This leaf-spot of the elm has been very common in the vicinity of Lincoln. The spots are $^1/_{18}$ to $^1/_8$ inch in diameter and are scattered over the entire surface. Each spot is due to a cluster of minute black pustules surrounded by a border of light-colored dead tissue. The fruits are not matured until after the leaves have fallen, when the spore fruits grow out through the surface of the leaf and discharge the spores (spring). The disease is also reported from Sarpy, Webster, and Cass Counties. A premature defoliation of badly infected trees is the only injurious result. (50)

POWDERY MILDEW, *Uncinula macrospora* Peck.—Observed only at Lincoln. Not very abundant, occurring mainly in rather shaded locations. (51)

FIR, RED, *Pseudostuga mucronata.*

SEEDLING-BLIGHT. (See Pine.)

HAWTHORN, *Crataegus* sps.

RUST, *Gymnosporangium macropus* Lk.—The cluster-cup stage of the fungus is common at Lincoln on cultivated species of Hawthorn. (See also apple-rust and "cedar-apples.")

LEAF BROWNING.—In this trouble, which has been observed only at Lincoln, the leaf is thickly covered with minute, dark brown pustules, which are very closely set, in many cases being confluent. In the leaves in which the disease is well advanced the spaces between the pustules are colored a pronounced yellow. The pustules are due to the destruction of the inner portion of the epidermis and the accumulation of large irregular globules of a fatty material. No parasitic organism is found in connection with this disease.

HONEY-LOCUST, *Gleditschia triacanthos.*

BLACK-LEAF, *Leptostroma hypophylla* B. and Rav.—In the first stages of this disease the leaflets appear covered with minute black specks on the under surface. These specks later become confluent and the whole leaflet is thus blackened. Some of the leaflets turn yellow and fall without the development of the characteristic appearance. Beneath the epidermis of the black spots minute conidia are abjointed from the erect hyphae. Spore-fruits are produced later. Specimens of this disease were obtained only from the nursery at the Experiment Station. (50)

TWIG-BLIGHT, *?Phoma.*—This disease has been observed quite frequently in the vicinity of Lincoln. The leaflets turn yellow and drop off, leaving the bare leaf-stalks still in connection with the leaves. The writer has seen whole tops of large trees almost defoliated by this fungus. The fungus is present just beneath the epidermis of both twigs and leaf-stalks. The fruits have not yet been observed.

HONEYSUCKLE, *Lonicera* sp.

BLIGHT, *Macrosporium* sp.?—Observed only on a cultivated species at the Experiment Station. The leaves are covered with irregular gray blotches upon which brownish conidial tufts may be seen. Similar conidial tufts are quite conspicuous on the silvery gray twigs. Extent of injury not yet determined.

LILAC, *Syringa vulgaris.*

POWDERY MILDEW, *Microsphaera alni* (Wallr.) Wint.—Very common, at least in eastern part of state. Not particularly injurious.

MAPLE, *Acer dasycarpum.*

BLACK- or TAR-SPOT, *Rhytisma acerinum* (Pers.) Fr.—Very common in vicinity of Lincoln, but not as abundant as last year. Not reported from other parts of the state, but certainly present in the entire eastern half. (53)

BROWN LEAF-SPOT, *Phyllosticta minima* (B. and C.) Ell.—Observed only at Lincoln. Not as abundant as last year. (50)

MULBERRY, *Morus* sp.

LEAF-SPOT, *Cercospora pulvinata* Sacc. and Wint.—Quite common at Lincoln. Causes but little injury. (50)

OAK, *Quercus macrocarpa.*

LEAF-SPOT, *Marsonia martini* Sacc. and Ell.—Numerous circular yellow spots $^1/_{12}$ to $^1/_8$ inch in diameter scattered over the leaf are characteristic of this disease. Observed only at Lincoln. (50)

POWDERY MILDEW, *Microsphaera quercina* (Schw.) Burr.—Observed only at the Experiment Station, but rather rare. Fruiting occasionally. Not injurious. (51)

PINE, *Pinus* sps.

SEEDLING-BLIGHT, *Cladosporium herbarum* (Pers.).—In the last part of April this disease was reported from the Forest Reserve at Halsey. The specimens examined were 1-year-old seedlings of Jack Pine and Yellow Pine. The same disease was prevalent on the seedlings of Red Fir and Blue Spruce. The terminal leaflets were dead and curled, while the main axis for about 1 cm. from the tip was dead. Dark hyphal patches were present on the dead leaves and the tissue was pervaded by a typical *Cladosporium mycelium.* Pure cultures of the fungus were made and seedlings of *Pinus ponderosa* inoculated by spraying the spores over the surface. After the lapse of a week the tips of the leaves were dead and infested by the fungus mycelium. The disease did not, however, progress any further, so it may be that the seedlings in the seed-beds at Halsey only succumbed to the attacks of the fungus as the result of a weakened condition from some other causes.

A large number of the seedlings at Halsey were affected, but the exact loss was not reported. Correspondent says, "It has killed most of our Jack Pine and Blue Spruce, and is quite common among the Red Fir, but less so among the Yellow Pine."

TWIG- and NEEDLE-BLIGHT.—A disease of pines in which the twigs die and the needles turn brown and fall was observed at the Experiment Station on young trees of *Pinus* *sylvestris* in the nursery and also on older Jack Pine trees on the campus. The twigs are covered with minute black specks, immature fruit produced by a fungus living in the cortex. This trouble was especially serious on the trees in the nursery, nearly all being killed. The young trees were transplanted quite late in the season, which seriously disturbed their nutrition, and put them in a weakened condition. It is doubtful if the fungus alone would have caused the death of the trees.

SPRUCE, BLUE, *Picea parryana.*

SEEDLING-BLIGHT. (See same for Pine.)

SUMAC, *Rhus glabra.*

LEAF-SPOT, *Cercospora rhoina* Cke. and Ell.—Observed only at Lincoln. The spots show as irregular dark brown patches that often drop out, producing the shot-hole effect. (51)

TREE-OF-HEAVEN, *Ailanthus glandulosa.*

LEAF-SPOT, *Cercospora glandulosa.*—One or two quite conspicuous brownish spots produced on each leaflet. The discolored spots fall out quite early, leaving the leaflets perforated by irregular openings.

WAHOO, *Euonymus atropurpureus.*

POWDERY MILDEW, *Microsphaera alni* (DC.) Wint.—Lincoln. Not fruiting abundantly. (51)

WILLOW, *Salix* sps.

RUST, *Melampsora farinosa* (Pers.) Schroet.—Observed at Lincoln on *Salix fluviatilis* and *Salix amygdaloides.* Only the *uredo-sori* were found. (52)

VII. HOUSE AND GARDEN ORNAMENTAL PLANTS.

BEGONIA, *Begonia* sp.

NEMATODE ROOT-GALLS, *Heterodera radicicola* Greeff.—Reported only from Beatrice, Gage County. Apparently not very injurious. (59)

BRYOPHYLLUM, *Bryophyllum calycinum.*

LEAF-SPOT, *Macrosporium?*—Observed only at Lincoln. This leaf-spot shows as areas of brownish tissue ¼ to ¾ inch in diameter somewhat sunken and covered with the minute brown conidial tufts. (57)

CARNATION, *Dianthus caryophyllus.*

BUD-ROT, *Fusarium* and a mite.—In this disease the petals rot, either before the flower opens or after it has opened. In severe attacks the bud may never open, while in less severe cases the flower opens partially, but begins to rot before it is fully expanded. The cause of this trouble has not been definitely determined, but Fusarium hyphae are always present in the rotting petals. A constant accompaniment of the fungus is a small mite of the family Tarsonemidae. This is a new and hitherto undescribed species and probably represents a new genus.[1] The relation between the fungus and the mites has not been worked out, so it is impossible to say which is the cause of the disease or what the relation really is. The supposition is that the mites act as carriers of the spores, thus inoculating the buds. As soon as the petals begin to rot, the mites find ideal conditions for their development. Flowers that are well advanced in this disease show the female mites as oblong watery looking objects, ⅛ inch in length or much less, buried in the soft mass of rotting petals. The watery sacs are the distended abdomens of the mites full of young ones.

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[1] Dr. Wolcott in paper read before the Nebraska Acad. Sciences, Jan. 1905.

The variety of carnation which is most seriously affected is the Lawson. Other varieties are, however, not exempt. The only treatment reported is to pick off the rotting flowers and destroy them. One house reports the loss of $1.50 to $2.00 worth of carnations daily. The disease has been observed at Lincoln, and specimens of the same trouble have been received from Beatrice. (55)

Experiments with pure cultures of the fungi are in progress.

RUST, *Uromyces caryophyllinus* (Schrank.) Schrt.—Carnation rust has been observed at Lincoln only, but it is not very abundant. (61)

STEM-ROT, *Fusarium* ? and *Rhizoctonia.*—Stem-rot troubles all growers of carnations consulted. It has been reported from both greenhouse and field, at Lincoln and Beatrice. One grower reports a loss of 25 per cent in the field; 1 per cent or less is reported for houses.

CENTURY PLANT, *Agave americana.*

ANTHRACNOSE, *?Melanconium.*—An anthracnose has been observed on plants at Experiment Station. Large irregular brownish patches somewhat sunken below the leaf surface characterize the disease. The surface of the sunken area is more or less wrinkled and in the center it shows a dark brown powdery mass of spores and spore-producing hyphae arranged in concentric circles. The diseased areas are very readily reproduced by inoculation on pieces of the leaves in a damp chamber.

CHRYSANTHEMUM, *Chrysanthemum sinense.*

LEAF-SPOT, *Septoria chrysanthemi* Car.—Not uncommon. Lincoln. Causes a considerable amount of defoliation, especially the lower leaves of plants. Loss is rarely sufficient to kill the whole plant, except in neglected houses. (57)

POWDERY MILDEW, *Oidium chrysanthemi* Rabenh.—Observed only at Lincoln. The fungus was more abundant on the stems than on the leaves. In some cases the stem just below the flower bud was completely covered with the white tufted growth of the mycelium. The flowers in such cases remained very small and did not expand fully, while the petals were completely overrun by the fungus. The disease was not very abundant. (60)

PETAL-ROT, *Botrytis ?*—A petal rot was observed in one house at Lincoln. The central petals do not open in this disease, but remain curved inwards in a compact mass. When separated these petals show a brown coloration, and minute fungus hyphae are generally visible. A *Botrytis* species is the only fungus found. In some of the flowers, thrips also were found, but they do not appear to be constantly present. Studies of pure cultures are in progress. (55)

GOLDEN GLOW, *Rudbeckia laciniata.*

POWDERY MILDEW, *Erysiphe cichoracearum* DC.—Reported only from Lincoln. In severe cases causes a considerable amount of defoliation. (60)

HYDRANGEA, *Hydrangea hortensis.*

LEAF-SPOT, *Macrosporium ?*—This disease was observed only in greenhouse specimens of Thomas Hogg. All specimens of this variety were very badly affected, while other varieties on the same bench were almost exempt. The disease shows at first as small brownish spots with purple borders. The spots at first are more abundant near the apex of the leaf, but they enlarge rapidly as the disease progresses and more spots appear towards the base of the leaf. After the spots have become quite abundant the intervening tissue is pervaded by the hyphae and finally turns brown and dies. The whole leaf may be killed in this way. Crowding on the benches favors the development of the disease. (57)

MUEHLENBECKIA, *Muehlenbeckia platyclados.*

POWDERY MILDEW, *Erysiphe polygoni* DC.—Reported from Red Cloud,[1] Webster County, on house plants. According to correspondent: "One plant, 6 inches high, lost every leaf, but later produced new foliage." Spore fruits were present. (60)

OLEANDER, *Nerium oleander.*

LEAF-SCORCH.—This trouble was observed on plants that had been kept in the potting house for a number of days in poor light conditions, and then moved into the greenhouse. The dead areas extended from the tips of the leaves back along the midrib. The central portion turned a silvery gray, and this was bordered by narrow strips of silk green, followed by olive green.

PANSY, *Viola tricolor.*

DOWNY MILDEW, *Peronospora violae* DeBy.—Reported only from Webster County. Killed every plant in the garden where observed.

PEONY, *Paeonia* sps.

LEAF-SPOT, *?Cladosporium paeoniae* Pass.—In this disease irregular brownish spots appear on the leaves, or a considerable area of leaf tissue near the apex or margin of the leaf may be affected. The dead areas often fall out.

roots received from York[1] County. Observer reported the plants doing well and apparently not injured by the attack. Available literature does not mention the occurrence of nematodes on peony roots.

ROSE, *Rosa* sps.

LEAF-BLOTCH, *Actinonema rosae* (Lib.) Fr.—Observed on various cultivated varieties at Lincoln and also reported from Thayer County. A considerable amount of defoliation was produced by this fungus. (56)

LEAF-SPOT, *Cercospora rosicola* Pass.—Reported only from Lincoln. Not especially injurious. (56)

NEMATODES, *Heterodera radicicola* Greeff.—Observed more frequently in the greenhouse than upon the lawn. The leaves of plants affected begin to turn yellowish and then brown at the margin and gradually die, but remain upon the plant for a considerable time. Greenhouse men in some cases call the trouble "leaf-scorch," not associating the above symptoms with the occurrence of nematodes in the roots. (59)

POWDERY MILDEW, *Sphaerotheca humuli* (DC.) Burr. and *S. pannosa* (Wallr.) Lev.—The first species is common in greenhouses. Reported from Lincoln and Beatrice. Greenhouse men report that the disease is controlled by applying oil and sulphur to the steam-pipes. The second species has been reported on garden roses from Saline and Lancaster Counties. One correspondent reports that one application of potassium sulphide was effective. (60)

RUST, *Phragmidium subcorticum* (Schrank.) Wint.—Reported from Webster, York and Sarpy Counties. One

VERBENA, *Verbena* sps.

POWDERY MILDEW, *?Erysiphe cichoracearum* DC.—On cultivated varieties in greenhouse (Lincoln). Not fruiting. (60)

VIRGINIA CREEPER, *Parthenocissus quinquefolia.*

LEAF-SPOT, *Phyllosticta ampelopsidis* Ell. and Mart.—Reported from Lincoln. Produces a brown spotting of the leaf with the minute spore fruits on the upper surface. The dead areas fall out very early, producing a marked shot-hole effect. In many leaves nearly half of the leaf tissue is lost by this means. Most abundant on vines growing on the south side of buildings. (50)

POWDERY MILDEW, *Uncinula necator* (Schw.) Burr.—Not common or injurious. Lincoln. (60)

VIOLET, *Viola odorata.*

LEAF-SPOT, *Alternaria violae* Gall. and Dors.—Greenhouse specimens received from Gage County, and from Lincoln. Extent of injury not indicated. (58)

ROOT-ROT. (Fungus not determined.)—Observed in greenhouse at Lincoln, but not very abundant.

PREVENTION AND TREATMENT OF THE MOST IMPORTANT DISEASES IN THE REPORT FOR 1905.

I. TREE FRUITS.

1. BLACK-KNOT, Cherry, Plum.

1. Prune off the branches bearing the knots early in the

2. Destroy wild plums and cherries that are infected, as the disease will spread from these to the cultivated varieties.

2. BLACK-ROT (*Sphacropsis*), Apple, Pear.

1. Remove dead limbs and twigs and destroy.
2. Scrape the large canker spots and apply copper sulphate solution (1 ounce to 1.5 gallons water). After that has dried, coat the wound with tar or paint.
3. After crop is harvested and during harvesting, collect and destroy all diseased fruit, including "mummies" and fallen specimens that are rotting.
4. The spraying used for scab will be valuable in this disease also.

3. BROWN-ROT (*Sclerotinia*[1]), Apple, Plum, Cherry, Pear, Peach.

1. Remove all "mummies" and fallen fruit, and destroy.
2. Remove and burn all affected twigs, and keep the trees well pruned in order to admit light and air.
3. Use insecticides, especially to control the plum curculio, which opens the way for the easy entrance of the fungus. (Lead arsenate, 2 to 4 pounds to 50 gallons of Bordeaux.)
4. Spray as follows, especially on plum, peach, and cherry:

    (*a*) Before the leaves unfold (last of April), with copper sulphate (2 pounds to 50 gallons water).

    (*b*) Just before blooming, with Bordeaux mixture.

    (*c*) After fruit has set, with Bordeaux mixture and insecticide mentioned under 3. For peach, apricot, and Japanese plums, only ½ to ⅔ strength Bordeaux should be used, using 6–8 lbs. of lime.

    (*d*) Repeat (*c*) after 10 days or two weeks.

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[1] Sclerotinia produces a black rot of apples under certain conditions.

(*e*) After last treatment, if rot is severe spray once every 10 days or oftener with potassium sulphide, 1 ounce to 3 gallons of water, or copper sulphate 1 pound to 400 gallons of water.

5. Thin the fruit, especially peaches and plums. This will be valuable at times, and many of the rotting specimens may in this way be removed and destroyed.

6. Same as 4 under Fire-blight.

4. CROWN-GALL, Apple, Peach, Apricot, Raspberry, Blackberry.

1. Reject all affected nursery stock.

2. Avoid planting raspberry or blackberry between peach rows. The disease does not pass from the raspberry to the apple.

3. Treatment is of doubtful value; badly affected trees should be removed and burned. Some benefit may be derived from the removal of the knots at the crown on orchard trees, and then painting the wounds with a paste of copper sulphate and lime. Crown-gall on raspberry does not appear to be very injurious.

5. FIRE-BLIGHT, Apple, Apricot, Pear, Plum.

1. Prune back all dead branches, cutting several inches below the lower limit of dead tissue.

2. Sterilize the knife-blade by dipping in a corrosive sublimate solution or other antiseptic to avoid the transfer of bacteria to healthy branches.

3. Burn all diseased twigs and branches that are removed.

4. Practice culture that will give a strong, firm growth, rather than a soft succulent condition, and avoid poorly drained locations.

5. In regions where fire-blight is severe, select varieties that are the most resistant.

6. FLY-SPECK FUNGUS, Apple.

Use the treatment for scab.

7. FREEZING, Apple, Peach, Pear.

Treatment should vary in young and old trees.

1. Young trees that are badly frozen should have the smaller twigs and branches removed, and the larger branches that are frozen cut back to 1 inch to 1½ inches in diameter.

2. Older trees (7 years old or more) should be only moderately pruned. Dehorning is likely to prove fatal.

3. Blackening of the wood does not necessarily mean that the twig or branch is killed. In many cases this dark wood will be covered over by the new growth of the following season.

8. LEAF-CURL, Peach.

Spray with Bordeaux mixture, 5—5—50 formula, just before the buds begin to swell. This single treatment will very greatly reduce the amount of leaf-curl.

9. LEAF-SPOTS, Apple, Pear.

Spraying with Bordeaux mixture as for scab, with later sprayings if leaf spots are severe, will prove effective.

10. PLUM-POCKETS, Plum.

1. Prune back the affected parts, and destroy all plum-pockets that are formed. In extreme cases destroy the tree.

2. Do not use portions of an affected tree for making grafts.

3. In case No. 1 can not be carried out, spraying adjacent trees with Bordeaux mixture, just before the pockets become mature (mealy white) will check the spread of the fungus. (See p. 61, for strength of Bordeaux.)

11. POWDERY MILDEW, Apple, Peach, Plum, Cherry.

1. Apple trees treated for scab, peaches for brown rot, and plum and cherry for shot-hole will need no further treatment.

2. Trees in the nursery may be treated with potassium sulphide (1 ounce to 3 gallons water) or ammonium copper carbonate (1 ounce copper carbonate; ammonia to dissolve the copper; 12 gallons water).

12. RUST, Apple, Quince.

1. Spray with Bordeaux mixture as follows:

(*a*) As soon as the blossoms have fallen.

(*b*) Ten days to two weeks later. These two sprayings coincide with (*c*) and (*d*) of scab.

2. The following courses are open for treatment in connection with the red cedar:

(*a*) Remove apples from cedar tree and destroy, when practical.

(*b*) Spray cedars adjacent to orchard with resin Bordeaux mixture just before the first crop of spores is produced on the apple leaves, and at intervals thereafter. The effectiveness of this treatment has not yet been demonstrated.

(*c*) The cutting of cedars adjacent to the orchard may be adopted as a last resort.

13. SCAB, Apple, Pear.

1. Spray as follows:

(*a*) Before the buds open, with copper sulphate solution[1] (2 pounds to 50 gallons water). This spraying does not appear to be essential for scab, but is of more especial value for black-rot.

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[1] Bordeaux may be used for this spraying if desired.

(*b*) Just before blossoming, with Bordeaux mixture[1] plus 2–4 pounds of lead arsenate to each 50 gallons as an insecticide.

(*c*) Soon after the blossoms fall, same as under (*b*).

(*d*) Repeat (*b*) ten days or two weeks later in case of a wet season.

2. Clean culture, with proper cultivation and proper pruning will lessen the amount of scab. It should be borne in mind that the scab fungus winters on the fallen leaves, hence their destruction is important.

3. Resistant varieties, such as Patten's Greening, Ben Davis, Whitney, Wealthy, etc., may be selected for growth.

14. SHOT-HOLE, Cherry, Plum.

1. Spray with Bordeaux mixture as follows:

(*a*) Before the buds open.

(*b*) Just after the leaves have unfolded.

(*c*) Ten days to two weeks later.

(*d*) If disease is severe, trees should be sprayed after the fruit has been picked.

2. Select varieties that are resistant, as the Early Richmond. It is probable that with proper spraying the very susceptible English Morello can be grown.

15. SOFT ROTS.

1. Practice clean culture in the orchard.

2. Spray for scab and insect enemies which bite or bore into the fruit.

3. Use care in handling to prevent bruising or breaking the skin.

4. Store in clean, dry, cool rooms with temperature under 45°F.

5. Sort stored fruit, and remove and destroy all decaying specimens.

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[1] For details in preparation of Bordeaux mixture, see Bull. 88, Nebr. Exp. Sta.

16. SOOTY FUNGUS, Apple.

Treatment for scab will hold this disease in check.

17. TRUNK-ROT, Apple, Cherry.

1. In pruning, protect wounds with coating of tar or paint.
2. Protect trees from sun-scald, and treat all canker spots as recommended for black-rot canker.
3. Destroy all sporophores or fungus fruits that appear on wounds and dying branches. Destroy fallen branches and all dead branches that are removed.

18. TWIG-GIRDLE, Apple.

The only treatment that can be recommended at present is to remove the dead limbs and twigs, cutting several inches below the lowest girdle. Burn all dead branches removed.

II. SMALL FRUITS.

19. ANTHRACNOSE, Raspberry, Blackberry.

1. Cut out the worst diseased canes and destroy.
2. Spray as follows:
   (*a*) Copper sulphate (2 pounds to 50 gallons water) before the foliage is formed.
   (*b*) Bordeaux mixture after the leaves are formed.
   (*c*) Repeat the Bordeaux spraying after the crop has been harvested.
3. Do not start new plantations from any of the affected stock.

20. BLACK-ROT, Grape.

1. Destroy all diseased fruit as soon as it appears.
2. Practice clean culture with the destruction of fallen leaves and trimmings before growth begins in the spring.

3. Spray as follows:

(*a*) Copper sulphate (2 pounds to 50 gallons water) before growth begins in the spring.

(*b*) After foliage is formed, with Bordeaux mixture at intervals of two to three weeks.

(*c*) A few weeks before ripening use only ammoniacal copper carbonate (see Powdery Mildew of Apple) or weak copper sulphate solution.

21. DOWNY MILDEW, Grape.

The same as for Black Rot of the grape.

22. LEAF-SPOTS, Blackberry, Raspberry, Currant, Gooseberry.

1. Leaf-spots if severe can be controlled by spraying with Bordeaux mixture or other reliable fungicide when the leaves are young, with later applications according to need. In ordinary light attacks no treatment other than good culture will be necessary. Sprayings made when the fruit is on should be with a clear fungicide to avoid staining the fruit.

2. Rake and burn all dead leaves and rubbish from plats that had badly infected plants. This will materially lessen the disease.

23. LEAF-SPOT, Strawberry.

1. Spray with Bordeaux mixture as follows:

(*a*) Just as the leaves unfold.

(*b*) After the petals fall.

(*c*) Once after the fruit has been picked, and if the disease is severe the spraying should be repeated.

2. In the fall the plants may be mowed and burned, or a straw covering may be burned.

3. Select varieties that are resistant.

24. ORANGE RUST, Raspberry, Blackberry.

1. Remove and burn plants that show the characteristic orange-colored blisters, as the fungus is perennial.
2. Do not take young plants for propagation from among those infected with the fungus.
3. If the disease is very abundant, its spread to healthy plants may be prevented by spraying with Bordeaux or other fungicide early in the season.

25. POWDERY MILDEW, Gooseberry, Currant.

Spray with potassium sulphide (1 ounce to 3 gallons water) as soon as the leaves unfold, and repeat at intervals if necessary. If desired, Bordeaux mixture may be used until the berries are half grown, but should be discontinued after that, as it would stain the fruit.

III. GARDEN VEGETABLES.

26. ANTHRACNOSE, Bean.

1. Avoid damp and poorly drained situations.
2. Badly infected fields should be planted to some other crop.
3. Avoid seed from infected fields as the disease can be spread from infected seed.
4. Spraying with Bordeaux mixture or other reliable fungicide at intervals of two weeks until the pods are ripening has been recommended.

27. ANTHRACNOSE, Cucumber, Melon.

Spray with Bordeaux mixture as follows:

(*a*) When the vines begin to run.

(*b*) Repeat the spraying every 4–10 days, according to the vigor of growth of the plants. The spraying should be often enough to keep all of the leaves protected by a covering of Bordeaux.

2. The spores of the fungus persist in the soil, hence rotation of crops will lessen the disease, as will also the destruction of all the dead vines. (For details of treatment, see Farmers' Bulletin 231, U. S. Dept. of Agriculture.)

28. BLACK-ROT, Cabbage, Cauliflower, etc.

1. Watch plats where the disease is suspected, and pick off the infected leaves from the young plants as soon as they can be detected.
2. Destroy all plants that show a blackening of the fibers in the base of the leaf-stalk. This can be detected by breaking off the lower leaves close to the stem.
3. Remove all refuse and decayed matter from the field and destroy.
4. Practice rotation of crops and avoid low, damp soil.

29. EARLY BLIGHT, Potato.

1. Early blight can be controlled if spraying is begun early in the season. It is too late to wait until after the disease is established. Spray with Bordeaux mixture as follows:

    (*a*) When the plants are four to six inches high.

    (*b*) Repeat the spraying at intervals of about two weeks. Paris green may be added to the Bordeaux mixture as an insecticide at the rate of 8 ounces to each 45–50 gallons.

2. Destroy all vines from affected fields and practice rotation of crops. The disease does not affect the tubers.

30. LEAF-SPOTS, Beet, Celery, Tomato.

These leaf-spots may be controlled by the use of Bordeaux mixture. For celery leaf-spot, the later sprayings should be made with ammoniacal copper carbonate. (See Powdery Mildew of Apple.)

31. POWDERY MILDEW, Oyster-plant, Peas, etc.

1. Spray with potassium sulphide, ammonia copper carbonate, or Bordeaux mixture.

2. Destroy all affected plants at the end of the season, in order to kill the resting spores of the fungus.

32. RUST, Asparagus.

1. Remove all badly infected plants, and destroy the infected canes in the fall. Early cutting and burning is injurious.

2. Spray with resin-Bordeaux: 1–8 Bordeaux, 48 gallons plus 2 gallons resin solution. Resin solution has the following composition: Resin 5 lbs., potash lye 1 pound, fish oil 1 pint, water 5 gallons. Heat resin and oil until dissolved, cool slightly, then add lye, and required amount of water. Heat until the solution will mix with cold water. (See Bull. 188, N. Y. (Geneva) Agr. Exp. Sta.)

3. The sulphur treatment used successfully in California would be of doubtful value in this region.

33. RUST, Bean.

1. Select resistant varieties in case the trouble is prevalent.

2. Destroy all infected plants after harvest.

3. Practice rotation of crops.

34. SCAB, Potato.

1. Two treatments of seed are effective:

Formalin treatment.

(*a*) Immerse the whole potatoes in a solution of formalin (½ pint to 15 gallons water) for two hours.

(*b*) Spread the potatoes out to dry and then cut and plant in the usual manner.

Corrosive sublimate treatment.

(*a*) Immerse the whole potatoes in a solution of corrosive sublimate (2½ ounces to 15 gallons water, prepared by dissolving the corrosive sublimate in hot water and diluting to 15 gallons) for 1½ hours. This is a deadly poison, consequently all treated tubers should be planted to avoid danger.

(*b*) Spread the potatoes out to dry and then cut and plant in the usual manner.

2. Practice crop rotation, and avoid infected land.

35. WHITE RUST, Cabbage, Horseradish, Radish, Turnip, etc.

This disease is generally not very severe in this region. The disease will be lessened by destroying all dead remains of these plants, and by keeping out cruciferous weeds that harbor the same disease. Rotation of crops is also advisable.

36. WILT, Cucumber, and other cucurbits.

1. The spraying recommended for anthracnose, with the addition of Paris green as an insecticide, will be of some value, but will not completely control the disease.
2. Pull and burn diseased vines as soon as they wilt.
3. Practice rotation of crops.

IV. FORAGE CROPS.

37. BACTERIAL BLIGHT, Soy Bean.

This disease is not well known at present. The following recommendations can [illegible] made

38. DODDER, Alfalfa, Clover.

1. Obtain seed that is free from dodder seed.
2. Spray infected areas with a 10 per cent solution of copper sulphate, or
3. Small patches may be treated by mowing, after which the material should all be raked into piles and burned. This should be done if possible before the dodder has seeded.
4. Large areas that are badly infected should be plowed up and planted to some crop that the dodder does not affect. Wheat, oats or brome grass may be used, or some cultivated crop like potatoes or corn, care being taken to keep out the weeds that would harbor the dodder.

39. ERGOT, Rye, Rye-grasses, Wheat-grasses, etc.

1. Cut all affected hay-grasses early in the season or about flowering time. This will prevent the formation of the ergots, which are poisonous to live stock and which cause the spread of the fungus to other wild or cultivated species. Grasses in waste places should be similarly treated.
2. Hay lands on which ergots have been matured may be burned over with some profit, as this will destroy some of the sclerotia.
3. Use only seed that is free from ergots. Rye, timothy, bluegrass, and other species are affected.

40. LEAF-SPOT, Alfalfa, Clover.

1. Frequent cutting is quite effective for holding the disease in check.

V. CEREALS.

41. BACTERIAL BLIGHT, Sorghum, Kafir Corn.

Essentially the same measures should be adopted as were noted for bacterial blight of soy beans.

42. LOOSE SMUT, Oats; BUNT OR STINKING SMUT, Wheat.

The treatment now generally in use is the formalin steep. The application may be made as follows:

1. Add the commercial formalin (40 per cent) to water at the rate of 1 lb. to 50–60 gallons.
2. Immerse the seed in this solution for two hours, and then spread out to dry, or place the grain on the floor in a pile and sprinkle with the solution until thoroughly moistened, taking pains to shovel over rapidly to evenly distribute the moisture, and then cover with canvas or sacking for two hours. After this treatment spread out to dry.

The hot-water method formerly much in vogue is less reliable and more difficult to apply.

For bunt the copper sulphate method may be used as follows:

1. Make a solution of copper sulphate, 1 pound to 24 gallons water.
2. Immerse the grain twelve hours in this solution.
3. Immerse the grain five minutes in lime-water, made by slacking one pound of good lime and diluting to 10 gallons.
4. Spread the seed out to dry, taking pains to avoid a reinfection.

43. LOOSE SMUT, Wheat.

The only known relief at present is from the following:

1. The selection of seed from fields that are known to be free from smut. Rotation of crops should always be practiced.

2. Some relief is claimed by the use of the modified hot-water method as follows:

(*a*) Soak the grain for four hours in cold water, and set away in wet sacks for four hours more.

(*b*) Immerse in warm water (110°–120°F.) and move the container up and down several times so as to thoroughly moisten and warm the seed.

(*c*) Drain and immerse in hot water 132°–133°F. for five minutes and then spread out to dry.

The important points to be observed in this treatment are as follows:

(*a*) The maintenance of the right temperature, 132°–133°F., never allowing it to rise above 135° or fall below 130°. Control temperature by adding hot or cold water.

(*b*) Have the volume of hot water six to eight times that of the seed treated at any one time.

(*c*) Do not completely fill the receptacle in which the seed is treated, but allow room for the movement of the grain.

(*d*) Use one-half more seed per acre, and dry thoroughly before planting, especially if a drill is to be used.

44. Leaf Fungus, Wheat.

The knowledge in regard to this disease is rather imperfect at present, and the following points are based largely on the experience with this same disease in New

3. The disease is lessened by very careful cultivation of the soil. For example, if the soil is cultivated thoroughly before the wheat is sowed, so as to expose the spores of this fungus to the bright sunlight, many of them will be killed and consequently will not infect the new crop.

4. Burning of the fields after harvest will lessen the disease somewhat by destroying the spores that are lodged in the old stubble.

5. The treatment of the seed the same as for bunt will probably lessen the amount of the disease. In some cases this treatment has proved quite effective, and it is certainly of value in holding the stinking smut in check.

6. There is an indication that the fungus which causes this disease lives at times inside the wheat kernel. This being true, it will be well to avoid using seed wheat from fields that were known to be infected.

7. There are some differences in regard to the susceptibility of different varieties of wheat to this disease, hence it seems probable that the disease can be controlled to a considerable extent by selecting the more resistant varieties for use in those sections where the disease is particularly prevalent.

45. KERNEL-SMUT, Sorghum, Broom Corn, etc.

Although not thoroughly tried, it is probable that the formalin method described for loose smut of oats will prove effective. The hot-water method has been found valuable as follows:

1. Immerse the grain to be treated in water.
2. Dip the basket of grain to be treated in water at 110°–120°F., moving it up and down several times.
3. Drain, and then immerse in water at 135°F. for 10–15 minutes.
4. Spread out to dry as for other grains. See also important points noted above under treatment for loose smut.

46. NAKED AND COVERED SMUT, Barley.

The same treatment as recommended for loose smut of wheat has proved fairly effective. The only modification to be observed is that the seed should be subjected to a lower temperature, 126°–130°F.

47. POWDERY MILDEW, Wheat, Rye.

Powdery mildew has not been very serious on the cultivated cereals. The first three points mentioned under rusts apply also to the powdery mildew, as well as the rate of seeding. A dense growth will be more seriously affected than a thin or medium stand.

48. RUSTS, Wheat, Oats, Rye, etc.

Seed treatment is without effect, and spraying is out of the question. The following points should be noted:

1. Rust is most severe on low-lying, water-logged soils. Thorough drainage will tend to lessen the amount.

2. Fields free from weeds rust less than weedy fields, as a firmer and less succulent growth is produced, hence the importance of clean culture.

3. Wheat that is drilled rusts less than broadcasted as more sunlight is admitted.

4. Some varieties are more resistant than others:

(*a*) Durum wheats resist rust much more than the common varieties. They are especially adapted to the drier regions. Some varieties of durum are more resistant than others.

(*b*) Hard Russian winter wheat varieties are more resistant than the ordinary varieties. Kharkof is one of the important resistant varieties.

(*c*) Some varieties of emmer show great rust re-

5. The use of early varieties is of importance, not because of any rust resistance, but because they mature before the rust reaches its maximum of severity. Sixty Day and Kherson oats may be mentioned as valuable for this reason. The hard winter wheats escape rust to a considerable extent, largely because of their earliness, and partly because of their resistance.

6. Careful seed selection from strong, rust-resisting plants will be of value in the various varieties, if pursued with system and vigor.

49. SMUT, Corn.

Seed treatment is entirely useless in corn smut. The following will be of value, and should be observed:

1. Rotation of crops. Smut is much worse on fields planted to corn for several years in succession.

2. The smut tumors may be collected at husking time and burned. This will only lessen the amount of the smut as many small tumors will be left in the field on leaves and stalks.

3. Avoid throwing smut tumors into manure heaps, and if smut has been severe do not use fresh manure on the field. The smut spores multiply with enormous rapidity under such conditions.

4. Plant only varieties that are thoroughly acclimated. Southern varieties produce more vigorous vegetative organs and consequently smut worse.

VI. FOREST AND ORNAMENTAL TREES AND SHRUBS.

50. LEAF-SPOTS.

The leaf-spot diseases are rarely severe enough to require any special treatment. On young trees in the nursery they can be controlled very readily by the use of Bordeaux mixture or other reliable fungicides. Whenever possible the destruction of the fallen leaves in any affected plantation is advisable.

51. POWDERY MILDEWS.

The powdery mildews on large trees are seldom able to do any serious damage. On shrubs and on young trees in the nursery they may be treated as recommended for the powdery mildew of the apple.

52. RUST, Cottonwood, Willow.

Rusts of these species are lessened by the following:

1. By maintaining the trees in good healthy condition. Frequent cultivation, especially of young plantations, an avoidance of overcrowding and presence of sufficient moisture contribute to this healthy tone.
2. The burning of the leaves in the fall will lessen the severity of the disease, especially in epidemics.

53. TAR-SPOT, Maple.

In ordinary mild attacks no preventive measures will be necessary. In epidemics or severe attacks it would be advisable to rake and burn the affected leaves in the fall, as they carry the disease over the winter.

54. TRUNK-ROT, Catalpa, Cottonwood.

Trunk rot due to bracket fungi or similar forms will be largely prevented by:

1. Proper pruning and protection of open wounds.
2. The avoidance of mechanical injuries that will leave the wood exposed to the inroads of fungi.
3. The destruction of sporophores or fruiting bodies of the rot fungi.

VII. HOUSE AND GARDEN ORNAMENTAL PLANTS.

55. BUD-ROT, Carnation.

This disease is imperfectly known at present, but the following recommendations are to be made:

1. Practice clean culture with the destruction of all refuse that might offer a temporary lodging place for either fungus or mites.
2. Keep the moisture down to the minimum necessary for the healthy growth of the plants.
3. Pick off the affected buds as soon as they can be detected, and burn.

56. LEAF-BLOTCH AND LEAF-SPOT, Rose.

These diseases may be checked by spraying with:

1. Bordeaux mixture, or
2. Copper sulphate, 1 pound to 50 gallons of water.

57. LEAF-SPOTS, Bryophyllum, Hydrangea, Chrysanthemum.

These leaf-spots have been observed only in greenhouse plants. The leaf-spot of the Bryophyllum was not especially serious. The Hydrangeas were quite severely affected. The following treatment is recommended:

1. Keep the moisture down to the minimum necessary for the healthy growth of the plants.
2. Avoid overcrowding on the benches.
3. Spray with ammonia copper carbonate (see powdery mildew of the apple) or copper sulphate, 1 pound to 50 gallons of water.

58. LEAF-SPOT, Violet.

"It would seem that the solution of this problem of controlling the disease lies in preventing it by giving careful attention to the production of vigorous, healthy plant growth, rather than attempting to check the trouble after it has once gained a foothold." Dorset: U. S. Dept. Agr., Division of Veg. Phys. & Path., Bull. 23. For further details see this Bulletin.

59. NEMATODES, Roses.

1. The only really practical preventive measure is the sterilization of the soil used in the benches or pots by means of steam. This treatment should be carried out before the soil is used, as any effective treatment of plants already infected is difficult.

2. In soils not sterilized especial care should be taken to avoid an excess of water, as well as any increased acidity. Such conditions are favorable for the rapid reproduction of the nematodes. Some soils are well stocked with nematodes in the open. Care should be observed in selection of soil. Liming of infected soils will be of value.

60. POWDERY MILDEW, Rose, Chrysanthemum, Verbena, etc.

1. Potassium sulphide (1 ounce to 3 gallons) sprayed on the affected foliage is an efficient remedy. This is especially valuable for roses and other plants in the open.

2. Flowers of sulphur dusted on the affected leaves will check the advance of the disease.

3. Powdery mildew of roses is held in check in the greenhouse by painting the steam pipes with sulphur and oil.

61. RUST, Carnation.

1. Destroy all badly infected plants to check the spread of the disease.

2. Never use rusted plants for making cuttings.

3. Pay especial attention to proper methods of cultivation and soil selection in order to secure a healthy condi-

tion. Do not use an excess of water and especially avoid sprinkling the foliage at a time when evaporation is very much retarded.

4. If the above methods are not sufficient, spray with either Bordeaux mixture or potassium sulphide.

THE BLACK-ROT OF APPLES DUE TO *Sclerotinia Fructigena.*

BY F. D. HEALD.

INTRODUCTION.

The rotting of various fruits of the Pruneae and Pomae, due to *Sclerotinia fructigena* (Monilia), has generally been characterized as the "brown-rot" and the symptoms attending this rot have not been described as differing materially in the different fruits, especially in American and English literature. It should be noted, however, that some German writers have described a "black-rot" of apples due to Monilia.

HISTORICAL.

The brown-rot is stated by Massee[1]* to be the most abundant on the apple, affecting shoots, leaves, and even flowers in England. The symptoms of the disease on the fruit may be noted from the following quotation:

"On the fruit, the first indication of the disease is indicated by the appearance of brownish scattered patches on the skin. This is followed by the appearance on the surface of small tufts composed of chains of spores. As the disease extends, the tufts of spores are generally in irregular circles around a central starting point." The symptoms as noted by Massee do not differ essentially from the symptoms given for the brown rot on other fruits. Frank[2] does not differentiate the symptoms, but states that according to Von Thumen,[3] apples and pears attacked by Monilia withstand rotting longer than the sound apples lying on the ground with them, and that Hallier[4] attributed this to the exclusion of yeasts and other decay-producing organisms. No different symptoms are given by Von Tubeuf and Smith[5] for Monilia on the apple, and a figure is given showing the typical concentric circles of conidial tufts. No mention of black Monilia apples is made by Prillieux,[6] so we may reasonably infer that this condition was not known to him.

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*The reference figures in this article refer to bibliography at end of article (pp. 90–91).

That American pathologists are not generally familiar with the black Monilia apples may be inferred from the following quotations:

"Occasionally this (Monilia) causes the rotting of ripe apples. It does not seem to be specifically different from the brown rot of the peach, q.v."[7]

"It soon produces a complete rotting of the infected apples which turn a brown color, and show the presence of the fungus by the breaking out of small, greyish, dense pustules of spore-bearing mycelium. The fruiting sori are usually found only when the fruit is in a moist place, especially when it has fallen on the damp earth, though they are sometimes seen on apples hanging on the tree."[8]

"September 26, an apple still hanging to the tree was fully enveloped with the fruiting tufts of Oidium, the tissues throughout being a uniform light brown color. The outside was removed to make herbarium specimens and in twenty-four hours it was again covered with a growth of spores."[9] Arthur mentions two different cases of rotting which were characterized by the dark brown coloration, but the latter one was apparently only due to *Sphaeropsis malorum* Berk. The black Monilia apples were evidently not known to him.

Jones[10] in considering "apple scald" says: "A light brownish tinge appears at first, either in fairly well-defined spots, or more or less diffused over the surface. The discolored areas enlarge with more or less rapidity, fusing together until the entire surface of the apple may be involved. At the same time the color passes from a lighter to a dark brown shade and usually terminates in a 'black rot.'" It seems quite possible that this last change at least was due to the entrance of Monilia.

The Experiment Station bulletins published by Wilcox,[11] Halsted,[12] Beach et al.,[13] Kinney,[14] and Stevens,[15] all of which deal with apple diseases, do not even include a mention of *Sclerotinia* as an apple trouble, while Longyear[16] mentions it only as causing one of the soft rots that follow scab.

Quaintance[17] in his study of the brown rot of peaches, plums, and other fruits states that "pomaceous fruits as apples, pears, and quinces are subject to attack, but on these fruits the loss is much less." However, he mentions only the typical course of the disease.

Garman,[18] who has made a careful study of the brown rot in Kentucky, makes the following statement: "On apples these gray masses (conidial tufts) are not so commonly found, and often an apple may rot without yielding any of the fungus spores." No mention is made of the production of any change except the typical brown coloration.

A consideration of the above quotations makes it evident that the great majority of investigators have not been familiar with the black Monilia apples. It seems quite possible that the failure to mention this may be due to attributing the black apples that came to their attention to another fungus, *Sphaeropsis malorum* Berk., which is generally designated as the "black rot" fungus.

A few investigators have noted the production of black apples by *Sclerotinia fructigena*. Smith,[19] as early as 1885, noted this, as may be seen from the following quotation: "If we take an apple diseased with *Oidium fructigenum* in our hands we find the tufts of the fungus seated on a portion of the skin which covers a soft, brown and internally rotten portion of the apple; the fungus has in some instances the power of changing the *skin of the apple to a jet black color;* if we cut or break the apple we always find the parts underneath the fungus growth brown, watery, collapsed, decayed and very soft."

The following from German pathologists is worthy of note:

"In many varieties of apples the color produced by *Penicillium* and *Botrytis* is a 'miszfarbige' browning; on the contrary, by the penetration of Monilia, the skin often assumes a black color (Schwarzfäule)."[20]

"The black rot of the apple, in which the pulp is colored brown, and the skin black, is produced by the fungus *Monilia fructigena* Persoon, whose mycelium grows through the pulp, and produces more or less numerous whitish or light brown conidial tufts, often concentrically arranged on the surface of the fruit."[21]

From the last citations given it may be noted that while the black rot of apples due to Monilia has not been generally recognized, it has not been entirely overlooked.

During the last few years the writer has had his attention called repeatedly to apples which agreed essentially with the description given by Kirchner and Boltshauser,[21] except that the conidial tufts were constantly absent, and that no external evidences of the fungus mycelium were visible. The observations recorded by the last three investigators were not known to me at that time, and consequently some work was carried out before the trouble was accurately diagnosed.

COMPARISON OF MONILIA AND SPHAEROPSIS APPLES.

Since the Monilia black-rot and the black-rot due to *Sphaeropsis malorum* have apparently been somewhat confused with each other, it may be well to call attention to the external differences. In the Monilia apples the skin is a shiny, coal black, smooth and perfectly free from any external evidence of either the fungus mycelium or fruiting bodies. In the case of the Sphaeropsis black-rot, the surface of the apple is sometimes brown, and soon becomes dotted with minute black pustules which contain the pycnidia, or the areas between the pustules are darkened also, giving to the whole surface a dark brown or black color. The Monilia apples do not shrivel greatly as may be seen by comparing the normal Bellflower with the same variety which is completely affected with the rot (Pl. I). The specimen photographed had been kept in the laboratory a month before the photograph was taken. On the contrary, the apples affected with *Sphaeropsis* shrivel very rapidly, and become very greatly reduced in size, thus exhibiting a much more irregular, wrinkled surface.

EXPERIMENTS WITH CULTURES.

The fungi causing both kinds of black-rot were studied in cultures, and it was found quite easy to obtain pure cultures of either. In order to avoid any outside contamination the surface of the affected apple was carefully wiped with absorbent cotton saturated with mercuric chloride solution (1:1000) and then dried with sterile absorbent cotton. Using a flamed scalpel, an incision was made in the apple, marking off three sides of a rectangular area; this rectangular flap was turned back and a portion of the superficial pulp was removed and discarded. During the operation, the flap of epidermis projected over the opening, protecting it from the falling spores of the dust-laden air. A small portion of the deeper lying pulp was quickly removed and placed in the center of a poured agar plate. By this means pure cultures of the fungi in question were always obtained. Cultures Nos. 1 and 2, Plate II, were taken from the smooth, black apples that were thoroughly rotted, and both exhibited the typical Monilia mycelium and conidial tufts. The medium used was 3 per cent glucose agar, reaction +10. The photographs represent cultures three days old, and the concentric arrangement of the conidial tufts can be noted in the enlargement of culture No. 2, in the lower part of the plate.

Cultures Nos. 3 and 4 were taken from apples affected with what was supposed to be the common black-rot, *Sphaeropsis malorum*, and were made with the same precautions as in the preceding cases. A typical *Sphaeropsis* mycelium was developed, and it should be noted that the growth was very much more vigorous than in the case of the Monilia cultures. In both *Sphaeropsis* cultures represented, the mycelium has spread over nearly the entire surface of the medium, producing rather a loose, cottony growth. The immersed hyphae, however, show the typical dark or olive brown coloration, so that the culture appears quite dark from the under surface. By cultures of this sort it is possible to differentiate the two rots before they are far enough advanced to exhibit the typical symptoms. Monilia has been repeatedly isolated from the smooth, coal-black apples, and grown in pure cultures, such as those described above, so there seems little doubt that this fungus is the sole cause of the trouble. No other organisms, either bacteria, yeasts, or moulds, were ever found in the apples thus affected and this is in accord with the observations of earlier writers who were dealing with the Monilia rot of apples.[4, 9]

INOCULATIONS.

In order to confirm still further the results obtained, inoculation experiments were carried out in the laboratory, using precautions to prevent contamination. The apples to be inoculated were first wrapped in absorbent cotton, and this was saturated with mercuric chloride (1:1000). After 5–10 minutes the cotton was removed and the surface dried with sterile absorbent cotton, and the apples placed in sterile, damp chambers. The inoculations were effected by making small incisions in the epidermis and placing a few of the spores from one of the pure cultures in the incisions.

The results of the inoculations were different in a few cases, but all inoculations carried out were successful. The results may be summarized as follows:

1. In apples kept in damp chambers supplied with plenty of moisture and kept at laboratory temperature, the rot showed the typical brown coloration and the early appearance of the mycelium and the conidial tufts on the surface.
2. In apples kept in damp chambers supplied with only a small amount of moisture, the infected areas were brown at first, and then changed to a black color, while the hyphae and conidial tufts either did not appear on the surface at all, or only rarely.
3. Apples kept in a fairly dry air and at a temperature lower than room temperature showed most frequently the typical black condition and the entire absence of the conidial tufts.

It would seem from the observations and experiments here recorded that the black Monilia apples are at least partially due to the xerophytic conditions. The lack of the proper amount of moisture is apparently the most important factor, while the low temperature by retarding the growth of the fungus also contributes a part. It is worthy of note that in Nebraska the air is generally drier than in many other localities where Monilia has been investigated. This may be the explanation for the common occurrence of the black rot due to Monilia in this region.

CONDITIONS FAVORING THE ROTTING.

The conditions favoring the rotting may be mentioned in brief. They are not far different from those favoring the production of rots due to other organisms. The two principal ones are as follows:

1. An abundance of moisture, since moisture is necessary for the germination of the spores, and since the conidial tufts are only produced under such conditions.

2. Bruises, insect punctures, and scab spots and cracks, which open the epidermis, allowing the fungus to gain access to the pulp much easier than otherwise. Such injured apples are sure to be worse affected than perfect ones. It does not, however, seem necessary for the fungus to always gain an entrance in this way. Garman[18] has shown that the spores do not gain access in the fore part of the season through the unbroken skin, but that the infection takes place largely through the "eye." I have also had specimens of the black apples that showed no injury or breaks in the epidermis.

At the present time little can be said in regard to varietal differences. In Nebraska, the black Monilia apples have been obtained from three different varieties, the Bellflower, Duchess, and Wealthy, while the Winesap has been used in addition to these for inoculations. The yellow-skinned varieties seem to blacken the most readily after infection. Genet is mentioned by Garman[18] as a particularly susceptible variety.

PREVENTION.

Some of the same methods that guard against the spread of other rots will be equally effective for this, especially in those regions where the rot does not appear early in the season.

1. Treat for scab and other fungus diseases with Bordeaux mixture with the addition of insecticides to check the codling moth and curculio as much as possible. This is a valuable treatment for the lessening of all kinds of apple rots.

2. Strict orchard hygiene should be practiced by the removal and destruction of all fallen fruit. The black apples which dry up and either hang on the tree or fall to

the ground carry the fungus over the winter and should consequently be destroyed. This is equally true of "mummies" and rotting fruits due to other species of fungi. The same strict orchard hygiene should be practiced in other orchard crops, for the same fungus that causes the Monilia apples is also the cause of the rotting of cherries, plums, peaches, and pears and can be carried from one to the other.

3. As this rot, like many others, appears also after the fruit is picked from the tree, it is important that the storage room should be as dry as possible, airy and *clean,* and kept at a low temperature.

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Plate I.

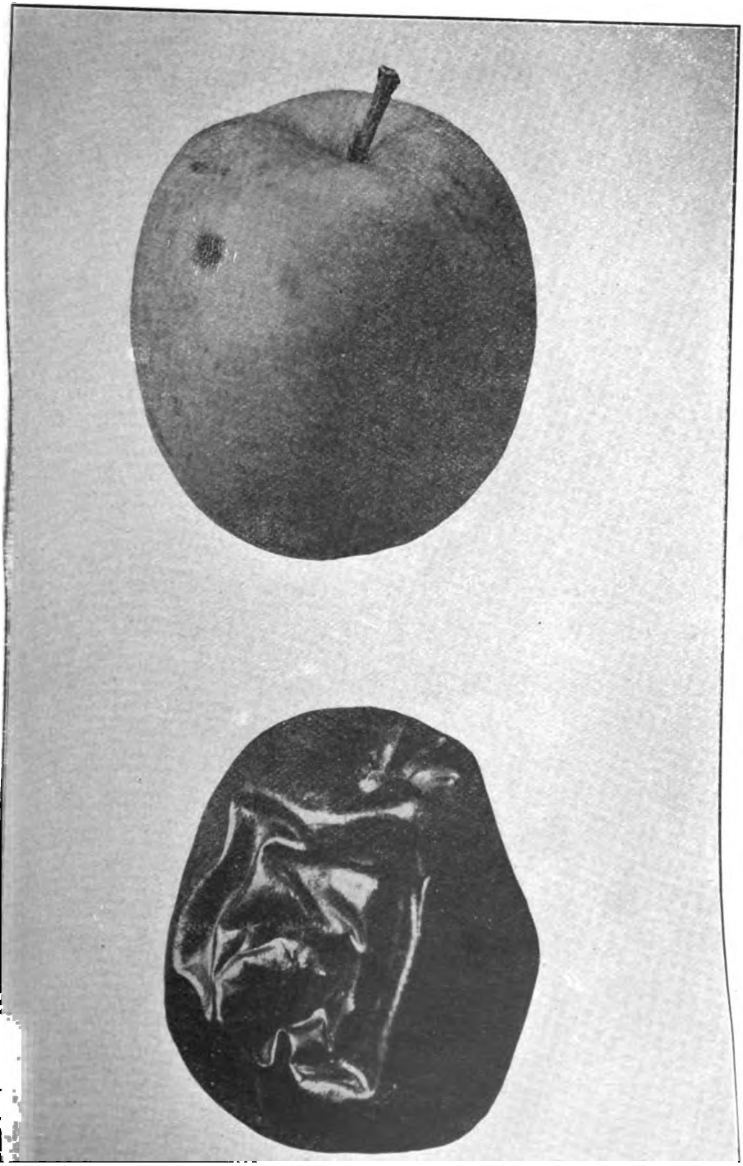
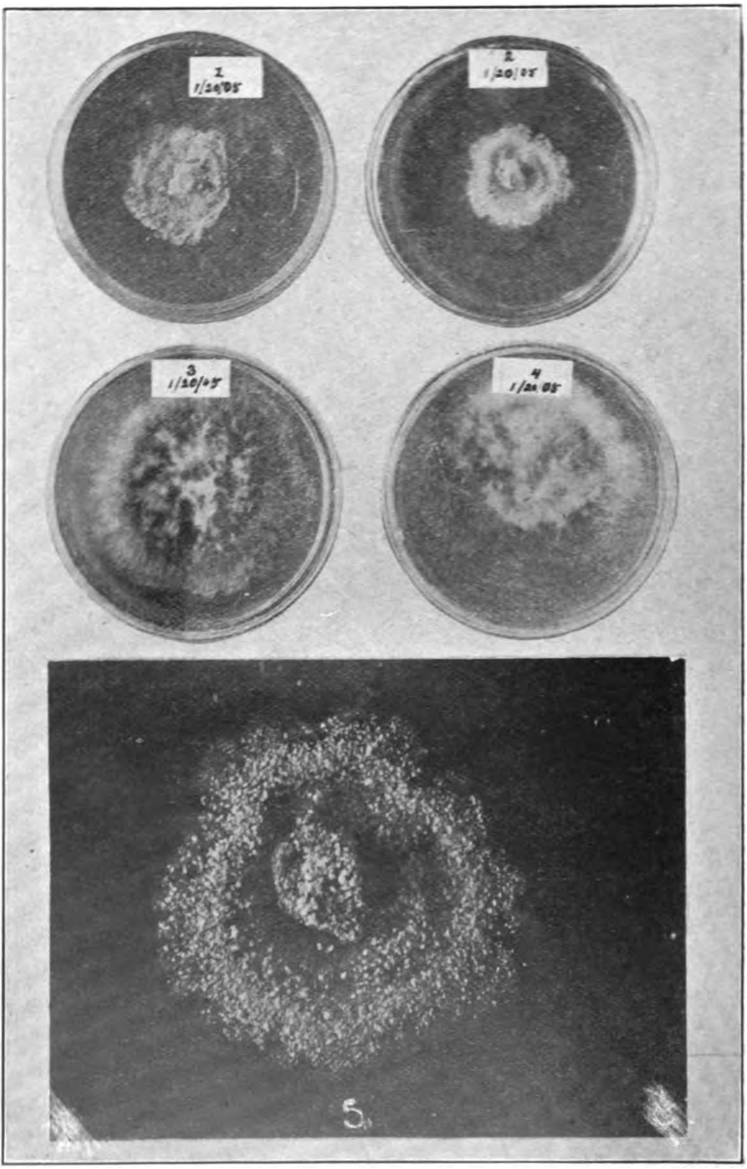


PLATE II.



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EXPLANATION OF PLATES.

Plate I.

The upper figure represents a normal Bellflower apple. The lower figure shows a Bellflower that had been infected with Monilia for over a month. It is perfectly black but without any external evidence of the fungus.

Plate II.

Figures 1 and 2 represent cultures of Sclerotinia 3 days old on 3 per cent glucose agar, obtained from typical black apples.

Figures 2 and 3 represent plate cultures of *Sphaeropsis malorum* of the same age and on same medium, obtained from typical *Sphaeropsis* apples.

Figure 5 represents a culture of *S. fructigena* enlarged, showing the concentric conidial tufts. Taken from culture No. 2.

A DISEASE OF THE COTTONWOOD DUE TO *Elfvingia Megaloma.*

BY F. D. HEALD.

During the past two years specimens of living cottonwood have been observed in which the entire heartwood and sapwood were pervaded by the mycelium of the fungus *Elfvingia megaloma,* producing a gradual dissolution or decomposition of the wood-cells, rendering the wood soft and punky in some places and brittle in others. This disease can hardly be characterized as a rot, as the change which takes place in the wood is due largely to the gradual digestion of the various elements of the wood by the growth of the fungus.

HISTORICAL.

The fungus which has been found to be the cause of the disease of the cottonwood under consideration, has not previously been reported as a parasite, or at most only as a wound parasite. Freeman,[1]* under the name of the "flattened pore-fungus rot" (*Fomes applanatus* (P.) Wallr.) records what is probably the same fungus as a "very common pore-fungus on old stumps and fallen logs, less commonly found growing from wounds on living trees," but the species of the hosts are not specified.

Most of the records of the occurrence of this fungus have been simply from the standpoint of the mycologist, and according to Murrill[2] it has been reported incorrectly under the name of *Polyporus applanatus* Pers., which is a synonym of *Fomes applanatus* (P.) Wallr.

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*The reference figures in this article refer to the Bibliography on p. 99.

No attempt will be made to consider these reports in detail, but perhaps the best statement of the general distribution of the fungus can be obtained by quoting from Murrill's recent work:[2]

"Specimens have been examined from New York, Canada, Pennsylvania, Virginia and nearly all other states west to California and south to Georgia. The plant occurs abundantly on dead and dying wood of oak, sweetgum, poplar, and other deciduous trees. In the popular mind it is associated with etching, because its hymenium changes to a darker color when bruised."

In my own work the fungus has been found as a parasite on the cottonwood in southeastern Nebraska, being reported from Cass, Johnson, and Nemaha Counties.

ETIOLOGY.

There can be little doubt that the fungus in question, *Elfvingia Megaloma* (Lev.) Murr., is the causal organism of the disease. Since the fungus has generally been referred to another species, *Polyporus applanatus* (P.) Wallr., by American mycologists, it may be well to quote from the revision of the *Polyporeae* by Murrill:[2]

"Owing to its close resemblance to *Polyporus applanatus* in habit and appearance, it has generally been known under that name by American mycologists. The correct name for it, however, appears to be that assigned to it by Leveille in 1846, on receiving specimens collected by Menaud in New York. In connection with his description, he notes that it is near *P. applanatus* in form, consistency, and volume, but differs essentially in the color of the cap, and the pores, and especially in the presence of a wide sterile border circumscribing the tubes below."

The following are the synonyms given:

Polyporus megaloma Lev. Ann. Soc. Nat. Bot. III. 5: 128. 1846.

Polyporus leucophaeus Mont. Syll. Crypt., 157. 1856.

Fomes megaloma Cooke. Grevillea, 14: 18. 1885.

Ganoderma leucophaeum Pat. Bull. Soc. Myc., 5: 73. 1889.

This fungus belongs to the *Polyporeae* or shelf fungi, a group which furnishes many of the important tree parasites and wood-destroying fungi. In the attacks of this fungus on the cottonwood, the vegetative mycelium enters at the base of the trunk near the ground line, or through wounds on the roots, and spreads upwards through the entire wood, reaching in specimens observed a height of ten feet. The entire wood of the lower portion of the trunk becomes thoroughly infested before the fungus attains sufficient vigor to produce its external fruiting bodies. In this condition the wood is rendered very brittle and the tree thus affected is poorly fitted to withstand the force of the wind in severe storms. If the tree is not blown down too soon, the fungus produces its fruiting structures or sporophores, which scatter the spores and make possible a spread of the fungus.

Plate I shows a single sporophore about eight inches long taken from a living cottonwood tree, about thirty-five years old. No observations are available to show the period of growth that must elapse before the fruiting structures are produced.

SYMPTOMS.

The first indication of the presence of the fungus in the living tree is the appearance of the sporophores, or fruiting bodies. These structures are small at first, and inably precedes the appearance of the sporophores, but is not generally noticed, or if noticed is not connected with the presence of the fungus.

PATHOLOGICAL ANATOMY.

An examination of the wood from a tree that is thoroughly infected with this fungus shows a very peculiar manner of growth. As the fungus grows upward, it appears to attack certain areas more severely than others. Plate II shows the surface of a slab that exhibits this feature of the growth. The severely infested portions of the wood seem to be arranged in quite marked horizontal strata, as may be very clearly noticed in the pointed end of the slab. The mycelium is not absent from the intervening areas, but is quite generally present. The appearance of the affected wood is shown more clearly in Plate III, the severely infected regions running generally at about right angles to the grain of the wood. These transverse strata are very soft and punky, and filled with a dense tangle of interwoven hyphae, while the intervening wood is much harder and is decidedly brittle. The difference between the two regions is so marked that at the first examination it was thought that the tree was infected with borers and that they were responsible for this effect. This effect was briefly noticed by one of my former students,[3] who recorded this fungus as a parasite. The naked eye examination of the cut surface also shows the presence of characteristic black lines that run in a general transverse direction, although they may deviate from this course to some extent.

The microscopic examinations of the sections of the infested wood show four steps or stages in the process of disintegration carried out by the fungus. The *first* effect of the invasion by the fungus is the complete disappearance of the starch which is stored in the medullary rays of the wood. The starch being readily digested is the first substance drawn upon by the fungus for its nourishment. The *second* effect is the digestion or removal of the lignin, for in this stage the wood-cells show only the cellulose reaction. In the firmer portions of the wood between the punky horizontal strata, perhaps this is the only change that has taken place. In most of this wood, however, the *third* step has been entered and a partial digestion of the cellulose walls has resulted. This condition is shown in Plate IV, figure 2, which represents a group of the wood-cells. The surface of the cell-wall bounding the lumen is seen to be irregularly corroded, and thin plates of the cellulose wall may be seen projecting into the cell cavity. At this stage the wall does not give any reaction for lignin. As the disease continues to progress, the cellulose lamellae become thinner and thinner and may be completely digested. (See fig. 3.) The *fourth* and last stage in the disintegration of the wood is the partial or complete digestion of the middle lamellae. The portions at the angles of the cells being thicker generally persist for a longer time, and in the soft punk-wood often very little of the original structure of the wood remains except these thickened portions entangled in a dense network of the fungus mycelium. In the severely infested wood, as for example in the punky spots, some further evidence of the original structure is visible. Plate IV, figure 1, represents a small portion of such wood, and this still shows the outlines of the medullary rays. The complete outlines of the large pitted ducts are also visible, but they are crowded full of the fungus filaments. All of the intervening wood-cells have only remnants of their original walls left and supported in the dense tangle of the fungus hyphae. Hartig[4] describes an effect similar to that given above in other wood-destroying fungi, while Von Schrenk[5] records a like power for various fungi that attack the New England conifers.

The black lines which were mentioned as a prominent feature of the decomposition by this fungus show in microscopic sections as yellowish deposits in the lumina of the ducts and wood-cells. In the region of one of these lines the cell-cavities are completely filled for a short distance with this deposit. A small portion of such a line, with portions of adjacent cells, is shown in Plate IV, figure 4. This section was taken from near the edge of the advancing mycelium of the fungus, and the appearance is suggestive. The hyphae have advanced up the duct, the wall of which is already partially digested, but as yet they do not seem to have been able to penetrate this line. It is suggested that the tree is endeavoring to check the advance of the fungus by plugging its cells with this deposit, which completely fills their lumina and is very difficult for the fungus to pass. The chemical nature of this substance has not been determined, but it is very difficultly soluble as it resists alcohol, ether, caustic soda, caustic potash, hydrochloric acid and is only slightly affected by strong nitric acid. A similar fact has been found by Von Schrenk[5] for the black lines in the wood of spruce and fir attacked by the mycelium of *Trametes pini.*

PROGNOSIS.

The disease is to be characterized as fatal to the life of the tree. The growth of the fungus may be quite slow, but there is no known way of checking its advance. The tree may be able to persist for some years, and form new sapwood outside of the affected wood, but the continual growth of the fungus results in a gradual weakening, and the tree is liable to be blown over before the fungus has had any opportunity to complete the work of destruction. The tree affected by this disease may be cut down and furnish good lumber, as the injury to the wood is only local.

In the cases observed the mycelium did not extend above ten feet in height, so that all of the trunk above that point furnished normal wood.

PREDISPOSING CAUSES.

The predisposing causes that may be mentioned are, *first,* the age of the host; *second,* mechanical injuries. No trees under thirty years old have been found that were affected with this disease. It would seem probable that the fungus, which is only a facultative parasite, is not able to attack young healthy trees, but that it can become parasitic on older trees in which the vitality has been considerably lowered, or that have reached the maximum of their development. Mechanical injuries of any kind favor the entrance of the fungus, and if the tree has not the vigor to check the advance of the mycelium, the disease will become established. It seems quite probable that the fungus gains an entrance at or near the ground level, so the presence of sufficient moisture for the external growth of the hyphae would be a favorable factor, and it appears that trees in low ground are for this reason more susceptible than those occupying places that are better drained.

PROPHYLAXIS AND TREATMENT.

There is no method of treatment that is of any value. Whatever is done must be in the nature of preventive measures that will check the spread of the disease to new hosts. Sporophores of this fungus should be removed and destroyed before they have had time to scatter their spores. The same is true for sporophores that are growing on dead logs. Any logs or wood affected with this fungus should be burned as the fungus can continue its growth. It seems quite probable that the vegetative mycelium is often the means of reinfection, rather than the spores direct. It has been shown that this same fungus mycelium which was living on the standing tree can continue its growth and produce sporophores, even when pieces of the wood are kept in damp places. In addition, care should be observed to prevent mechanical injuries that will permit the entrance of the fungus.

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EXPLANATION OF PLATES.

PLATE I.

Sporophore of *Elfvingia megaloma* on cottonwood.

PLATE II.

Section of cottonwood trunk showing the destruction of the wood by the mycelium of *Elfvingia megaloma.* Transverse section of punky wood alternate with strata in which fungus has not digested the wood.

PLATE III.

Portion of longitudinal section of wood showing the localized strata in which the fungus has destroyed the wood.

PLATE IV.

Fig. 1. Represents a transverse section through a small portion of punky wood: (*a*) represents a medullary ray; (*b*) vessel filled with interlacing hyphae; (*c*) wood-cells and hyphae. Only the thickened angles of the cells remain.

Fig. 2. Portion of a medullary ray with adjacent wood-cells in early stage of digestion: (*a*) the originally lignified portion of the wall which now gives only the cellulose reaction.

Fig. 3. Group of cells from a transverse section showing a more advanced stage in the digestion of the wood: (*a*) medullary ray; (*b*) vessel; (*c*) hypha; (*d*) wood-cell.

Fig. 4. Portion of a longitudinal section in the region of one of the dark lines: (*a*) wood-fibers; (*b*) vessel with bordered pits, partly digested below the black line, and filled with hyphae; (*c*) a yellow secretion that completely plugs the lumina of wood-fibers and vessels.

PLATE I.

PLATE II.

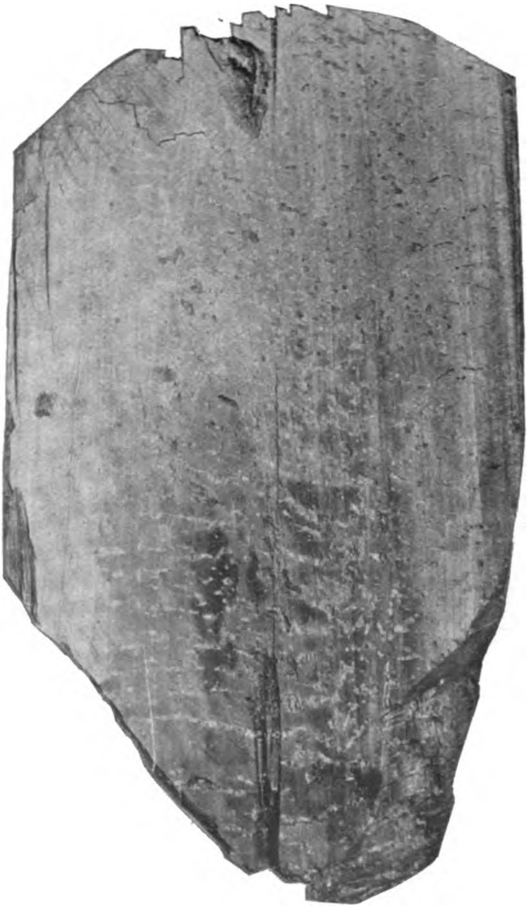


PLATE III.

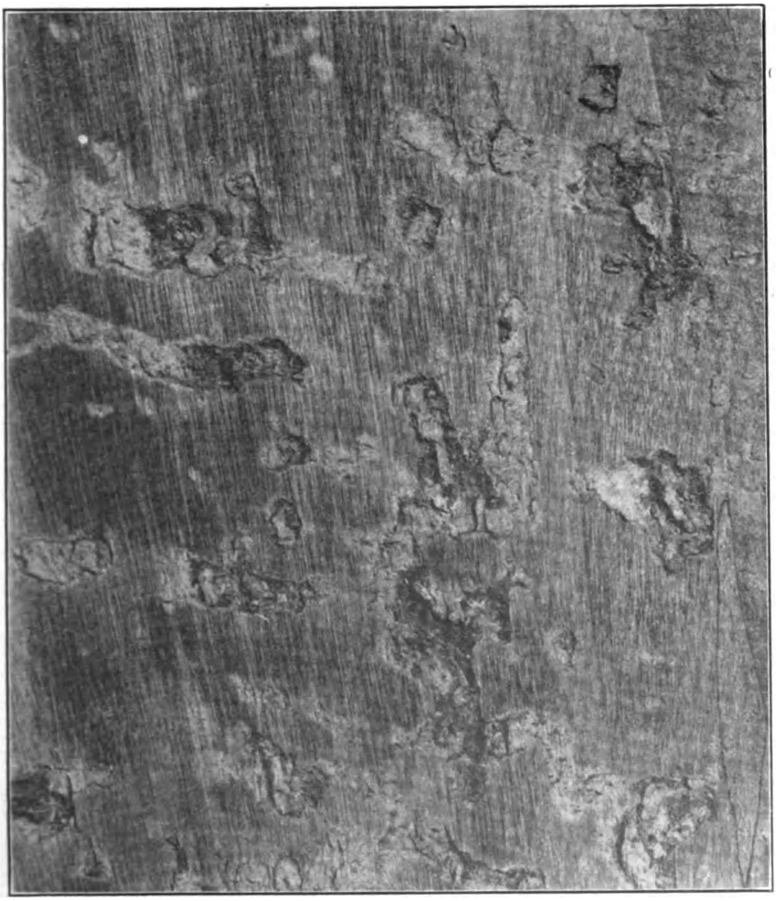
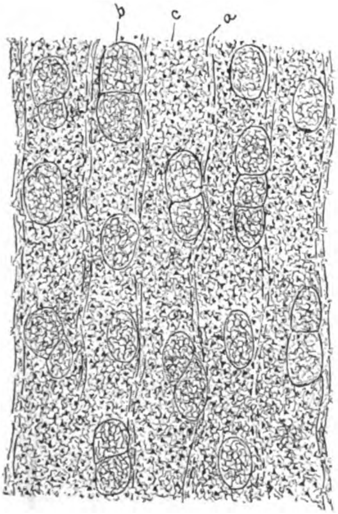


PLATE IV.



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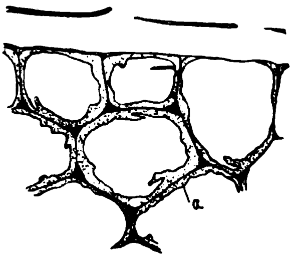

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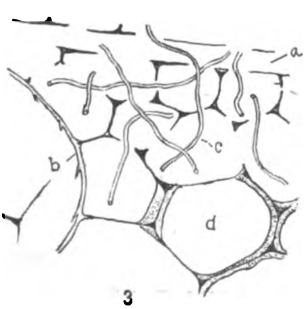

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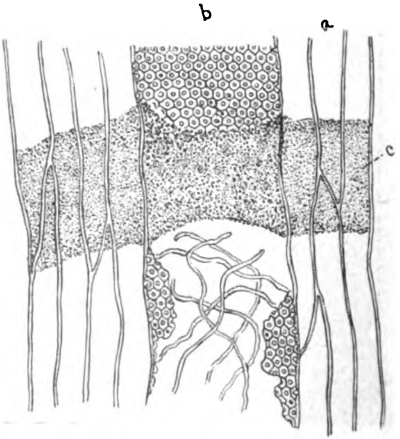

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THE RELATION OF EARLY MATURITY TO HARDINESS IN TREES.

BY R. A. EMERSON.

HARDINESS A MATTER OF HABIT OR OF CONSTITUTION.

That a tree with well-ripened wood is better able to withstand severe cold than one with immature wood is a matter of common knowledge. A tree which has its leaves and soft, new shoots killed in May by a temperature only a few degrees below freezing might, if well ripened, pass unhurt through a January temperature far below zero Fahrenheit. One would no more question this than that ripe seeds which pass uninjured through the cold of winter might have been produced by plants as tender as beans or corn. It is perhaps less commonly known that resistance to cold in trees is due often almost wholly to the habit of early maturity rather than to constitutional hardiness. A concrete example may help impress the truth of this. Some black walnut trees from northern seed growing at the Experiment Station, by virtue of their perfect maturity, passed through the extremely severe winter of 1898–99 without apparent injury, while similar black walnut trees from southern seed, owing to imperfect maturity, have had their new growth killed back from a few inches to two or three feet every winter for the past six years, and yet, not-no hardier than the southern ones, but that their greater resistance to winter cold was due to their habit of ripening their new growth perfectly in the fall.

The writer is of course aware that with some plants hardiness to cold is much more a matter of constitution than of habit. For instance, if pea and bean plants, both growing under the same conditions and both equally immature, were exposed to frost, the beans would doubtless be killed while the peas might be unhurt. But the object of this paper is to show the connection between early maturity and hardiness; hence, matters relating to constitutional resistance to cold will be passed over. From a study of relative hardiness of various trees, and through experiments aimed to increase hardiness, considerable material bearing upon the relation of early maturity to winter hardiness has accumulated. The most important of the data are presented here.

EARLY MATURITY AND HARDINESS IN FRUIT TREES A MATTER OF VARIETY.

PLUMS.—Peaches naturally grow late in fall and are comparatively easily injured by cold, while our wild plums ripen their wood early and are very resistant to cold in winter. The same relation exists between various types of plums. The accompanying illustration (fig. 1) shows the degree of maturity of the season's growth of various sorts of plums on September 19, 1902. The trees were all two years old and stood close together in the nursery. The presence of small, newly-formed leaves at the distal end of the Abundance, Wildgoose, and Pottawattamie of Wyant (Americana) and Cheney (Nigra) plums and sand cherry indicate that growth in length had ceased in the case of these trees, even by the 19th of September. Anyone who has ever grown these types of plums in the North knows that the Japanese, Chicasaw, and Hortulana types are injured by a less degree of cold in winter than are the other types seen in the illustration. The difference in winter hardiness commonly observed in Nebraska between the Abundance, Wildgoose and Pottawattamie plums is not indicated by the illustration, simply because the photograph was taken before either had begun to mature. Had the picture been taken a few weeks later, the hardier Wildgoose and Pottawattamie would doubtless have shown some degree of maturity, while the tender Abundance might still have been growing.

APPLES.—Varieties of apples illustrate well the relation between early maturity and resistance to cold. Figure 2 shows twigs of Whitney, Oldenburg, Prairie Crab, Wealthy, Ben Davis, Grimes, and a tender French crab seedling. All of these except the last named were taken from one-year-old root grafts in the Experiment Station nursery. The French crab seedling had finished its second season's growth, after having been lined out in a nursery. It was so very tender to cold that it froze to the ground during the previous rather mild winter. The twigs are shown with or without leaves, just as they were when collected in the nursery, and are arranged in order of hardiness, the tenderest at the right and the hardiest at the left. The ranking of these varieties with reference to resistance to cold winters is not only based upon the writer's personal observation but is in accord, it is believed, with the experience of fruit growers throughout the Northwest. The only variety the rank of which is at all questionable is Prairie Crab. The twigs were cut and photographed December 14, 1904. Had they been taken earlier, even greater differences in maturity would have been expected.

A variety like Whitney, for instance, usually completes its length growth by July, even in case of young, vigorous nursery trees, and, while it is probably not thoroughly ripened until much later, it has more of the appearance of ripeness in midsummer than a variety like Grimes has in late autumn. The twigs pictured in the cut, taken as they were in early winter, are of special value in showing the relative maturity of the different varieties at a time of year when any further ripening had been made impossible by the arrival of winter weather. It is interesting to note in this connection that the soft, undeveloped twigs of the French Crab were actually dead when cut, having been caught by winter's cold while still growing. The degree of ripeness of the twigs of two tender apples (French Crab and Grimes) and two hardy varieties (Oldenburg and Wealthy) is perhaps even better seen in figure 3, which presents longitudinal sections of the twigs. The left twig of each group was stained with iodine to show the deposit of starch in the pith, a very prominent feature of well-matured twigs. In case of practically all varieties of apple which the writer has observed in this connection, including many not shown in the cuts, the earliest to ripen their wood are the hardiest.

EARLY RIPENING AND HARDINESS OF TREES WITH RESPECT TO AGE.

It is very generally known that young trees are more susceptible to severe winter weather than older trees of the same kinds, except in case of trees that are so old as to be feeble from age. Nurserymen find it necessary to protect young plants, whether seedlings or from grafts, cuttings, etc., though they may need little or no protection after being set in the orchard. It is necessary here simply to point out the fact that young, vigorously-growing trees ripen their wood later in fall than older trees, and that this is at least in large part responsible for their lack of hardiness.

Figure 4 indicates something of the difference between the twigs of old and young apple trees. The varieties shown are Jonathan and Wealthy. The twigs were cut and photographed December 16, 1904. The twigs on the left in case of each variety are from one-year root grafts growing in the nursery, and the ones on the right are from old, bearing trees. The difference in maturity between old and young trees, even in case of so early ripening a variety as Wealthy, is quite apparent, and with the Jonathan the difference of course is even more noticeable.

EARLY MATURITY AND HARDINESS OF FOREST TREES FROM DIFFERENT LOCALITIES.

In the spring of 1897, seeds of several kinds of forest trees from various parts of the country were planted at the Experiment Station. The test was to have been carried on in cooperation between the Experiment Station and the United States Department of Agriculture, the latter having collected the seeds the previous fall. The Department of Agriculture, however, withdrew from cooperation after a year or two, leaving the work solely with the Experiment Station. The seeds were planted in nursery rows, where the seedlings have grown since. As the trees began to crowd, they were thinned, until at present only one average tree is left to represent each locality from which the seed was secured. The first records were made by Professor F. W. Card, then Horticulturist at this Experiment Station, or under his direction. The records since 1899 have been made by the writer.

BLACK WALNUT.—Seedlings from some states were injured during the first winter in the nursery and have been injured more or less severely every winter since. The trees from other states have never been appreciably injured, even in the severest winters. The illustration, figure 5, shows this difference well. The photograph was taken June 1, 1904, as the trees were starting on their eighth season of growth after having passed through a comparatively mild winter. Most of the injury shown in the case of the South Carolina and Georgia trees occurred during the more severe winter of 1902–03, as seen in figure 5 at *a* and *b*, but there was some injury in the following winter, 1903–04, as shown in figure 5 at *c*, *d*, *e*, *f*, and *g*. It is also noticed from the illustration that the trees from South Dakota and Nebraska seed suffered no injury during either of these winters, the growth being continued in each case from the terminal bud.

That there is a direct connection here between winter injury and degree of maturity may be seen from figure 6, which is from a photograph taken September 30, 1902. The tree from South Dakota seed was well prepared for winter, having ripened both its twigs and its leaves. The Nebraska tree was not far behind. It had lost most of its leaves. The trees from North Carolina, South Carolina, and California, on the other hand, were still in an immature growing condition, having lost scarcely a leaf. Figure 7 shows the condition of the young twigs of trees from South Dakota and South Carolina some ten days earlier. Even at this early date the South Dakota tree had lost most of its leaves. Figure 8 shows that by October 15th the Nebraska tree had lost all its leaves, while the trees from California and Oklahoma seed were no more nearly ready for winter than the South Dakota tree was a full month before, and the trees from South Carolina, North Carolina, and Georgia had even then lost almost none of their leaves. As a matter of fact, they actually held their leaves some two weeks longer and finally got ready for winter after the Nebraska tree had been ready a month and the South Dakota tree had been waiting a good six weeks.

That the difference in the time of shedding the leaves is accompanied by a real difference in the maturity of the new growth of these black walnut trees may be seen from figure 9. The twigs are shown as they appeared September 19, 1902, after the leaves had been removed. The terminal buds were well developed in the South Dakota and Nebraska twigs and the wood was thick and firm, while in case of the twigs from South Carolina and North Carolina trees the terminal buds were immature and the layer of wood near the top scarcely differentiated from the pith.

The fall maturity and the winter injury of trees from all the states represented in the test have been noted a number of times during the nine years' growth of the trees. From all these observations the trees from the different states are rated as to the earliness of their maturity in fall and also according to their resistance to cold during winter. This rating is given in the following table, where "1" indicates extreme earliness and hardiness, and "6" extreme lateness and tenderness to winter's cold.

TABLE I.—*Black walnut trees from seed from various states, ranked according to earliness and hardiness.*

States from which seed was obtained.	Rank of trees.	
	Earliness.	Hardiness.
South Dakota	1	1
Nebraska	2	1
Colorado	2	1
Iowa	2	2
Pennsylvania	2	2
Ontario	2	2
Missouri	2	3
Illinois	3	3
Ohio	3	3
California	4	3
Virginia	4	4
Oklahoma	5	4
Kentucky	5	5
North Carolina	6	5
South Carolina	6	5
Tennessee	6	6
Georgia	6	6
Alabama	6	6

There is here, certainly, a very close relation between early maturity in fall and hardiness in winter. Apparently these trees have adapted themselves to the length of the growing season in their native homes (whether through natural selection or direct effect of climate—influence of habit—does not appear) and do not easily change their habit of growth when moved to a new climate. While in general the Northern trees planted in Nebraska are earlier in ripening in fall and more resistant to cold in the winter than Southern trees, there is also something of the same difference between the Western and the Eastern trees in favor of the former. Perhaps this means that trees adapt themselves to short seasons of growth whether the season is cut short by early fall frosts as in the North or by dry weather in fall as in many parts of the West.

HONEY LOCUST.—Observations made in spring to learn the amount of winter injury sustained by the trees from different states, and observations in the fall to determine their relative time of ripening, show that honey locust trees are no exception to the rule established for black walnuts, namely, that trees accustomed to the longer growing season of states to the south of us do not at once adapt themselves to our comparatively short season, but continue to grow late in fall and are consequently injured more or less seriously by our cold winters. The relative difference in time of ripening between honey locust trees from various states and the degree to which they are usually winter injured are seen from the following statement:

TABLE II.—*Relation of earliness to hardiness in honey locust trees.*

States from which seed was obtained.	Time of maturity.	Amount of winter injury.
Alabama	Very late	Badly Injured
Kentucky	Late	Considerably injured
Kansas	Fairly early	Slightly injured
Ohio	Fairly early	Slightly injured
Nebraska	Early	Uninjured

Figure 10 shows the degree of ripeness of the new growth of Nebraska and Alabama trees on September 19, 1902. Although the trees from Nebraska seed still held their leaves, the length growth of their twigs had been completed for the season and they were ripening preparatory to winter. The trees from Alabama seed, on the contrary, had not completed their growth but still showed much soft wood and many small, growing leaves. Figure 11 shows twigs from Nebraska, Kansas, and Alabama trees as they appeared on the above date after having had their leaves removed the better to disclose the degree of ripeness of the new growth.

INDUCED EARLINESS AND HARDINESS IN PEACHES.

The connection between hardiness of trees and a natural tendency to ripen early has now been discussed. It remains to be shown that the unnatural earliness forced upon a naturally late-growing tree makes that tree resistant to cold.

HIGH LAND AND EARLY RIPENING.—Every peach grower in this region knows that he must plant his trees on high land if they are to come through the winter with uninjured twigs and fruit buds, and many growers know that the reason for this is that the trees continue growth later on low land than on high land. In 1901 young Wager peach trees growing on high land at the Experiment Station ripened their twigs early in fall, while similar trees on low land near by continued growth until the middle of October, though the trees in both situations received the same culture. During the following winter five of the eight trees on low land were killed outright and the other three seriously injured, having had their tops killed back perhaps one-half. The high land trees, on the contrary, came through the winter without injury except for some discoloration beneath the bark of the twigs.

COVER-CROPS AND EARLY MATURITY.—Tests at the Experiment Station have demonstrated that peach trees, which naturally grow late in fall, can be rendered much more resistant to cold winters by sowing a cover-crop in the orchard in midsummer to dry the ground enough to check the growth of the trees and cause them to ripen their wood well before winter. The results of the tests at the Experiment Station are borne out by the experience of fruit growers of this and other states.

The Experiment Station tests of the effect of cover-crops on the fall maturity and winter hardiness of peaches have extended over a period of four years. During this time the trees in the cover-crop plats have stopped growing and ripened their new wood from a few weeks to two months earlier than similar trees in adjoining plats that received late summer cultivation. Figure 12 illustrates the effect of cover-crops on early maturity of peaches. The twig on the left indicates the ripened condition of trees with cover-crops even in early fall when the trees given late cultivation are still growing rapidly as indicated by the twig at the right in the illustration. Figure 13 shows the effect of even a mild winter (1903–04) on peach trees in both the cover-crop and cultivation plats. The photographs were taken in May, 1904, and show representative twigs taken from the cover-crop and late-cultivation plats. It will be noticed that in case of the cover-crop trees there was very little injury and that most of the terminal buds had started growth; while with the trees given late cultivation the winter injury was severe, none of the terminal buds having started growth and some of the twigs having been killed back almost their entire length.

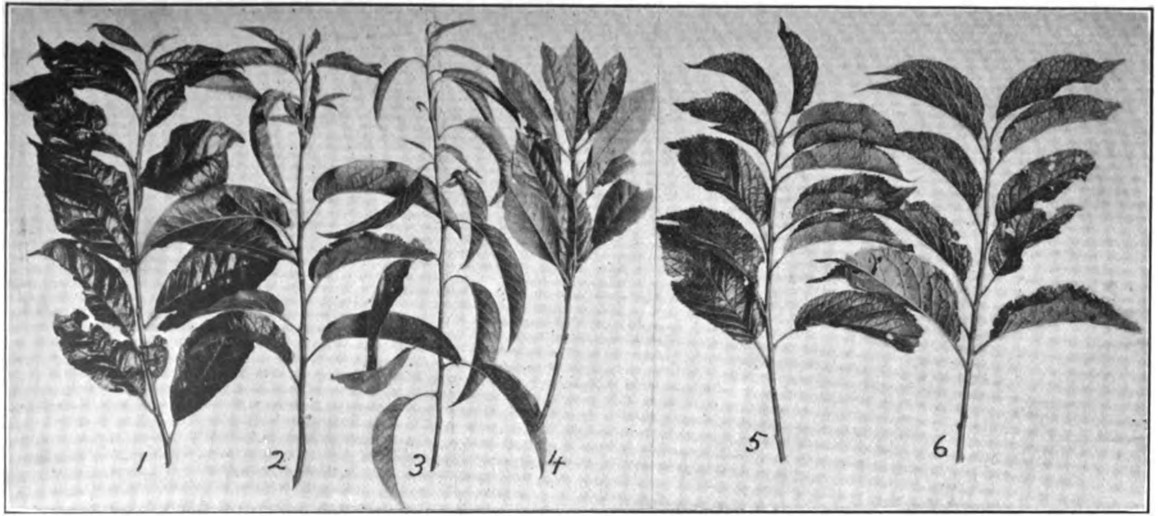


FIG. 1. Relative maturity of twigs of different varieties of plum on September 19, 1902. (1) Abundance, (2) Wildgoose, (3) Pottawattamie, (4) Sand Cherry, (5) Wyant, (6) Cheney.

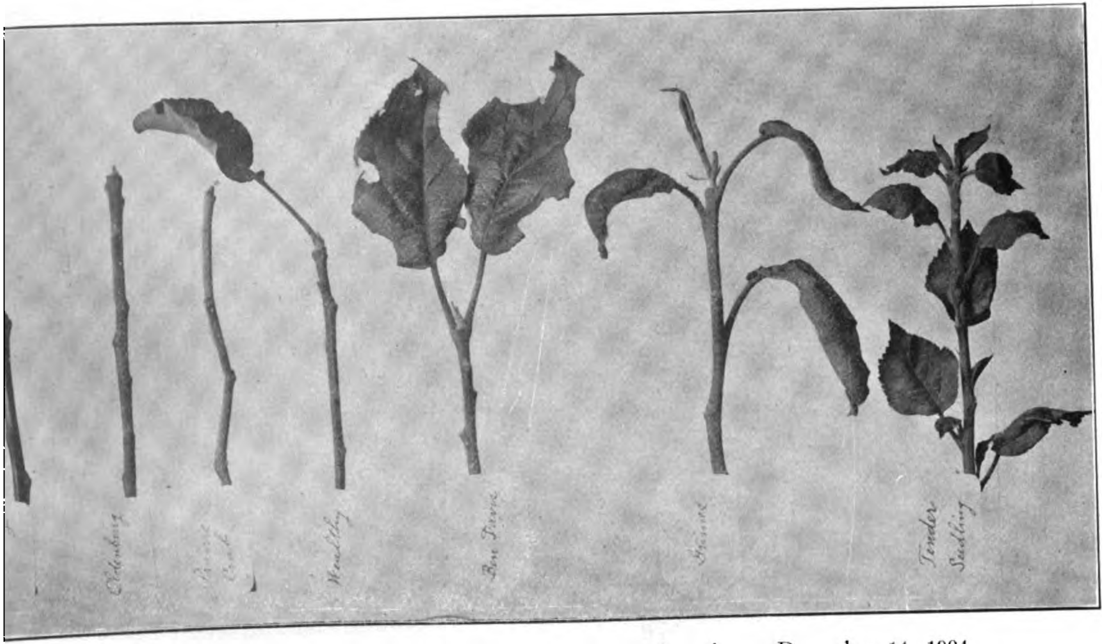
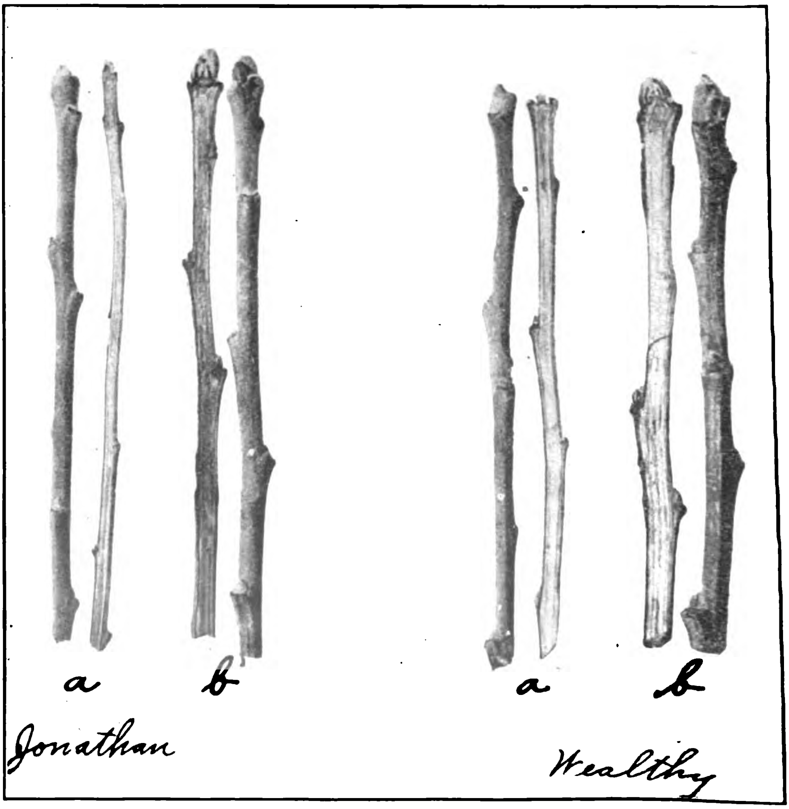


FIG. 2. Relative maturity of twigs of different varieties of apple on December 14, 1904.


a
b
a
b
Jonathan
Wealthy

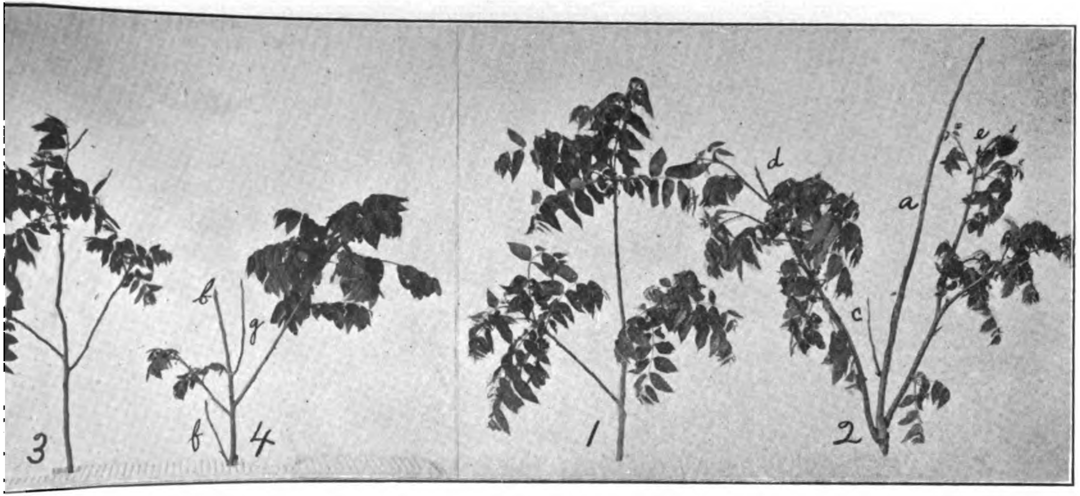


FIG. 5. Winter injury to black walnut trees grown from seed obtained in various localities. 1) Seed from South Dakota, (2) Georgia, (3) Nebraska, (4) South Carolina.

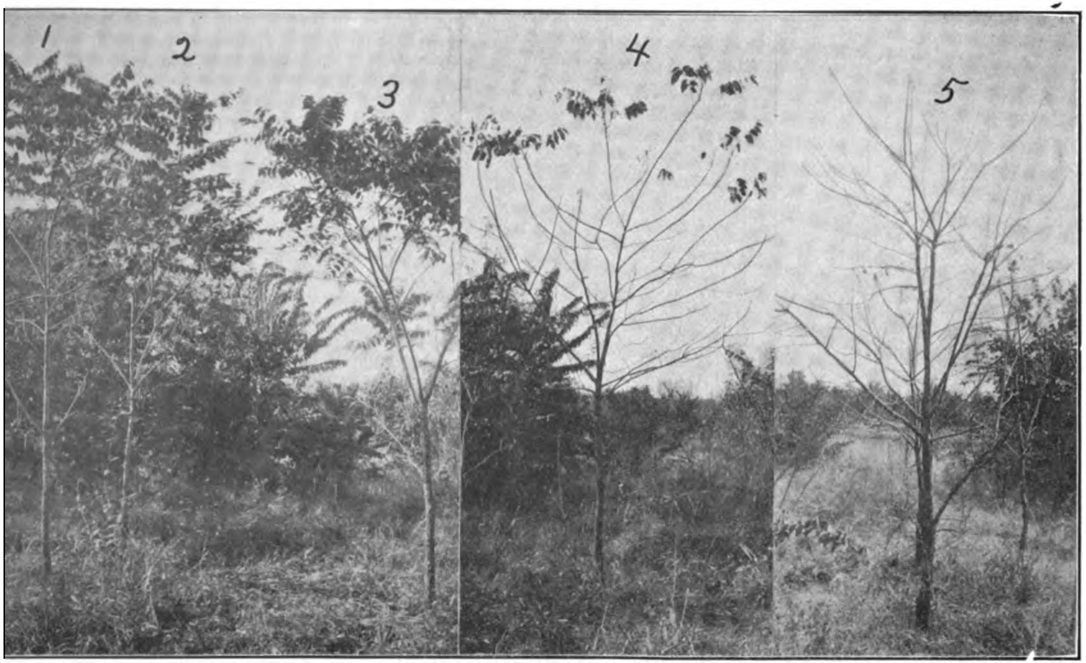


FIG. 6. Fall maturity of black walnut trees grown from seed obtained in various localities, as September 30, 1903: (1) North Carolina, (2) South Carolina, (3) California, (4) Nebraska, (5) h Dakota.

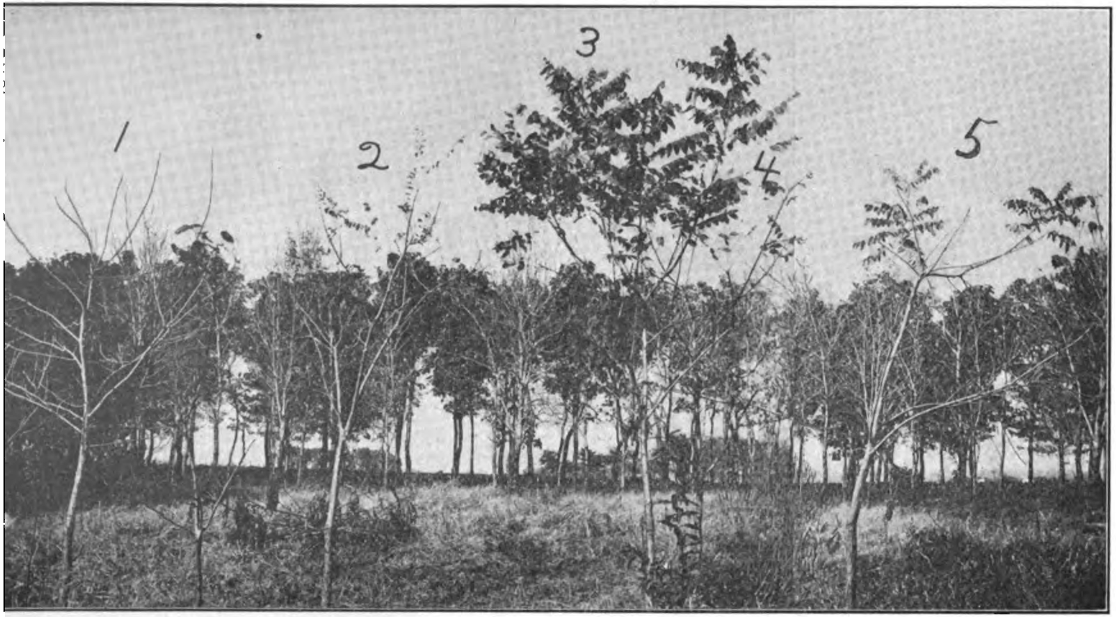


FIG. 8. Relative maturity of black walnut trees on October 15, 1902: (1) Seed produced in Nebraska, (2) California, (3) South Carolina, (4) North Carolina, (5) Oklahoma.

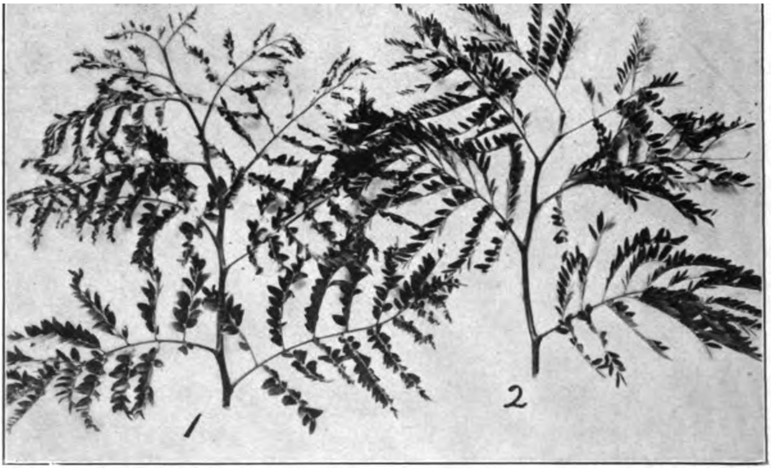


FIG. 10. Honey locust twigs, from a photograph taken September 19, 1902, showing (1) the immature condition of a tree from Alabama seed, and (2) the maturity of a tree from Nebraska seed.

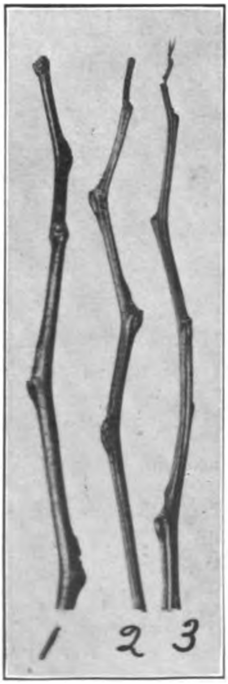


FIG. 11. Twigs of honey locust with leaves removed.

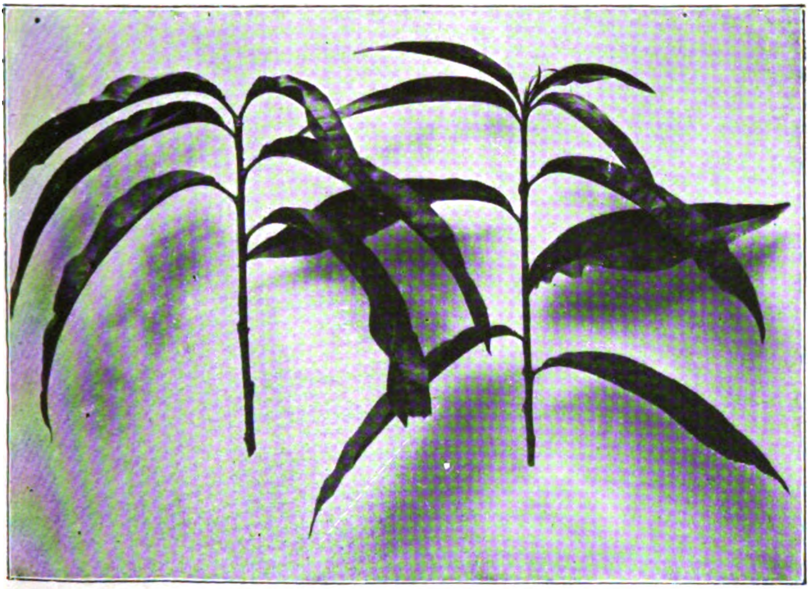
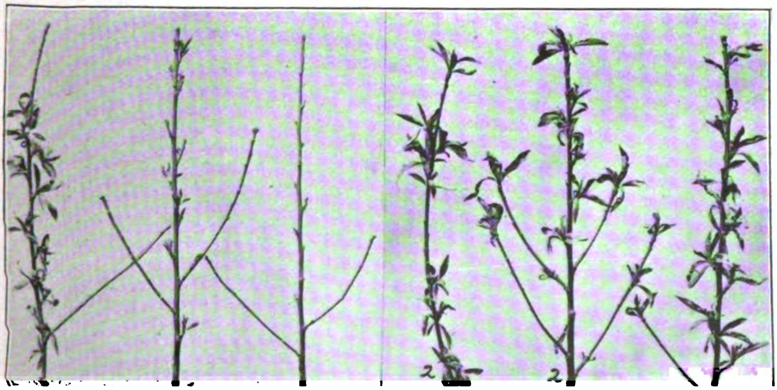


FIG. 12. Peach twigs showing the mature condition in early fall of trees with a cover-crop and the natural immature condition of trees given late cultivation.



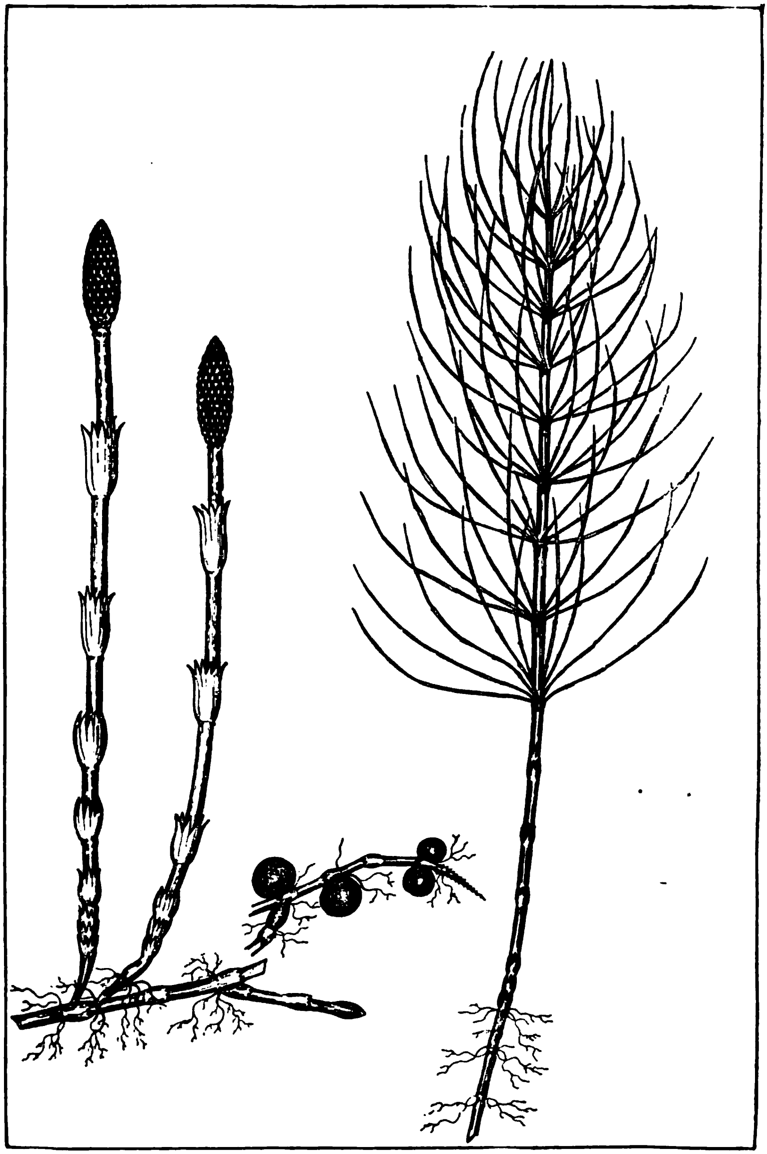
POISONING OF HORSES BY THE COMMON HORSE-TAIL WEED (*Equisetum arvense*).

BY A. T. PETERS AND L. B. STURDEVANT.

On the 8th of August, 1905, the Department of Animal Pathology in conjunction with the citizens of Valley, Nebr., began an experiment at that place to determine whether the common horsetail weed had been the cause of the many horses dying in that part of the state. We started with two horses, one a six-year-old gelding and the other an aged mare. These horses had eaten hay from meadows where the weed was found, so were considered fair subjects for the trial. The young horse had an incurable case of quittor which, however, when the experiment was begun, did not interfere with his gait. His mother had two bone spavins, but otherwise both animals were sound. The weed was not so plentiful as at first reported and the mare was taken off the experiment after three weeks, having eaten forty-six pounds of the *Equisetum* hay during that time without showing any of the characteristic symptoms.

No grain was fed. About fifteen pounds daily of wild hay was soon substituted by an equal amount of timothy and clover which was eaten up clean, while previously a great deal of the red top had been left every day. The horsetail weed was cut and cured for hay or picked by hand and then dried. Starting with a half pound per day of the *Equisetum* hay and gradually increasing to two pounds, this last figure was adhered to for the first two weeks when it was gradually increased to four pounds and then soon again to five pounds. There it remained until the middle of the fifth week when it was changed to six, where it stayed practically the same for the next seventeen days, the animal then refusing to eat it at all. At first we had mixed it with the hay, but as the horses seemed to pick it out from the latter by preference, we began feeding it as a separate ration and watched the animal until he had disposed of it, after which we would then put the timothy and clover ration in the box. After the first four days the mare showed marked aversion to the weed, as did the horse also on the twelfth. Care had to be exercised from then on to give them only the softer and the greener weeds and this obstacle gradually grew worse throughout the course of the experiment until finally it became insurmountable. This result does not tally with that of the Vermont Experiment Station (Bull. No. 95) on this subject, for they claim in their bulletin that the animals seem to acquire an increased or depraved appetite for the weed.

The first symptoms in the horse came very early, considering the small weed ration fed at the beginning. On the fourteenth day the animal exhibited a hesitating, crouching gait, showing a distinct partial loss of control over the muscles of the legs, appearing first of all in the left fore leg. This continued for about three or four days and disappeared to reappear with greater severity on the thirtieth day, this time remaining about three days. On the fortieth day the symptoms appeared again, this time persisting for seven days, and the gait seeming to favor the foot having the quittor. Following this for four days the gait was nearly normal again, after which it became distinctly worse and remained so for ten days more, even though the animal ceased eating the horsetail weed at this time altogether. No amount of care in mixing it with hay,



THE COMMON HORSETAIL. *Equisetum arvense.* The two upright stalks at the left represent the fruiting stems which are *pale yellowish* in color and come up in early spring, (April-May) from the rooting branch below. In the center is such an underground branch bearing bulbs or tubers. From these same underground parts the much-branched, many-jointed *green* shoots arise a little later (May-June) as represented at the right. These continue to grow all summer, and it is these which cause the poisoning. From nature, x½, by Mrs. W. J. Morse. (Courtesy of Vermont Experiment Station.)

A few other symptoms of importance were noted, agreeing in the main with the results of the Vermont experiment. The normal or sub-normal pulse and temperature, the pale or bluish mucous membranes, the trembling, staggering gait, the loss of muscular control, the good appetite, and poor condition in flesh were all present. In addition we noted the ease with which the hair could be pulled out, an unusual sensitiveness of the side and shoulder, probably due to the muscles, and a stiff condition of the latter appearing occasionally in the region of the neck, shoulder, and croup. Toward the last the animal developed a bad case of chordee, doubtless due to the same cause.

In general the attacks of staggering coincided somewhat with the rainy, cold days, but this rule did not last for more than the first half of the experiment. The total amount of *Equisetum* hay eaten by this animal was 205 pounds.

Among other less important data may be noted the following in connection with the younger animal:

The morning temperature (8 a.m.) varied between 99° and 100°F., and the evening (5 p.m.) quite regularly was found between 99.5° and 100.5°. The morning pulse ran from 35 to 42 beats per minute, the evening pulse from 38 to 45. Respiration was 12 per minute.

The urine remained distinctly alkaline throughout the course of the experiment, less so, however, toward the end. The diuretic properties of the weed were easily seen from the constant saturation of the ground with urine, and this effect was much less noticeable after the horse had refused to eat the weed. The urine remained normal in appearance.

No positive increase or decrease of nervousness was noted. The animal was of a rather vicious disposition by nature or by reason of previous treatment and was apparently easily frightened at any sight or noise, but after becoming more used to its new surroundings showed no more nervous symptoms than might be expected normally.

A few specimens of Oxyuris were passed and a few also of *Sclerostoma tetracanthum* in the feces.

An apparent rigidity of the muscles of the neck and croup was first noticed on the twenty-seventh day of the experiment. The animal would scratch the croup as though to relieve some unpleasant sensation. This phenomenon disappeared to return several times later with more or less severity. On the forty-seventh day an unusual extension and flexion in turn of the tail was noted. This also must be regarded as a related muscular effect.

The unusual sensitiveness of the side and shoulder referred to above was shown by very rigorous contraction of the panniculus carnosus on poking the animal in the side with a finger. The most sensitive point seemed to be right behind the shoulder.

The braced position of the horse in the latter part of the experiment was quite characteristic, the hind legs especially being widely apart as though the animal could maintain the standing position only in this way. The tremor of the muscles showed up distinctly at this stage. The animal at the same time grunted spontaneously or on walking.

A drooping of the ears and the injected conjunctiva which were seen at one time gave rise to suspicions that the animal was coming down with swamp fever, but the symptoms disappeared as suddenly as they had come.

Toward the last of the experiment, the horse losing control of his legs, fell in the stall many times, always getting on his feet again after more or less of a struggle. In this way he was badly bruised in a number of places over the eyes, on the angle of the ilium, on the legs, etc. About this time also the horse was more stupid, yawning frequently and showing less life than usual.

As a last resort, in administering the *Equisetum,* we made a decoction of one pound of the weed by boiling it in a pail of water for fifteen minutes and giving this to the animal to drink after cooling it sufficiently. After evident great dislike the horse drank about two-thirds of it one day and the rest on the day following. The only way this experiment could be followed out properly would be to prepare large quantities of the decoction and use it as a drench. The vicious disposition of the animal would have been the big obstacle in this case, so the attempt was abandoned here.

We can not be absolutely sure of results from two experiments only, and will continue work on the same problem when circumstances are again favorable. We can, however, be certain that the horsetail weed is not present in large enough quantity in the hay of Nebraska to be at all dangerous to horses. The weed in sufficient amount, however, is no doubt fatal to these animals.

This experiment ought to be continued some time during the winter and early spring, when *Equisetum* poisoning in horses is reported, to ascertain if climatic conditions, such as cold weather, have anything to do with it.

COPPER SALTS AS A SUPPOSED PREVENTIVE OF HOG CHOLERA.

BY S. AVERY.

The wide, and in many cases apparently unauthorized, publicity given to the work of the Bureau of Plant Industry of the U. S. Department of Agriculture with copper sulphate as a means of destroying certain noxious growths in water, has aroused in the public mind an unwarranted confidence in this substance as a preventive of certain diseases.

It seems to have occurred to many people almost simultaneously that hogs might be protected from the ravages of hog cholera by the simple expedient of adding a little copper sulphate to their slop.

At the suggestion of the writer and in cooperation with him the Department of Animal Pathology undertook experiment to determine the following points:

(1) Is a neutral or an alkaline copper solution less inclined to disturb digestion in hogs?

(2) Can hogs consume considerable quantities of copper salts with apparently no injurious results?

(3) Does the use of copper in slop have any effect in preventing hog cholera?

Two solutions were tested; namely, a solution of copper sulphate containing 1 lb. of crystallized copper sulphate per gallon, and a solution of the same salt containing enough Rochelle salts so that it could be rendered slightly alkaline without precipitation of copper compounds. After a trial of several weeks no difference in the action of the two copper solutions could be noticed.

Proceeding then with the plain sulphate solution the herdsman administered as high as one fluid ounce per hog a day for several days. When the amount was increased much beyond this the hogs refused to drink their slop freely. The treatment was continued several weeks, the herdsman varying the amount administered somewhat at his discretion. An occasional loss of appetite as the result of an overdose was the only result noted.

To throw light on the third point mentioned above, the hogs that had received the copper treatment were placed in pens next to hogs used as checks, and the treatment continued. The checks were given the same food without copper. The treated hogs and the checks seemed to be equally thrifty. The checks were then infected with material from a virulent outbreak of hog cholera and promptly became sick and died, showing all the symptoms of the disease according to the diagnosis and post-mortem examination by the Animal Pathologist.

In due time the copper treated hogs sickened and died with precisely identical symptoms and showed the same post-mortem appearance.

Unfortunately pressure of work did not permit the writer to make an examination of the location and amount of copper deposited in the bodies of the hogs, but it must have been considerable, as a relatively large amount was found in the ash from the cremated animals.

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TWENTIETH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF

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NEBRASKA AGRICULTURAL EXPERIMENT STATION

THE UNIVERSITY OF NEBRASKA

To His Excellency, George L. Sheldon, Governor of Nebraska:

SIR—In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Twentieth Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
Director.

The University of Nebraska, February 1, 1907.

GOVERNOR'S CERTIFICATE

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT

LINCOLN, February 1, 1907.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR—I hereby acknowledge receipt of the Twentieth Annual Report of the Nebraska Agricultural Experiment Station.

GEORGE LAWSON SHELDON,
Governor.

THE OFFICIAL ROSTER OF THE STATION

THE GOVERNING BOARD (THE REGENTS OF THE UNIVERSITY)

HON. CARL J. ERNST, Omaha, President	Term expires 1908
HON. ELISHA C. CALKINS, Kearney	Term expires 1908
HON. CHAS. S. ALLEN, Lincoln	Term expires 1910
HON. WILLIAM G. WHITMORE, Valley	Term expires 1910
HON. FREDERICK H. ABBOTT, Columbus	Term expires 1912
HON. VICTOR G. LYFORD, Falls City	Term expires 1912

J. S. DALES, Lincoln, Financial Secretary *

THE EXECUTIVE COMMITTEE

CARL J. ERNST E. BENJAMIN ANDREWS E. A. BURNETT

THE STATION OFFICERS

E. A. BURNETT, B. Sc	*Director*
W. W. MARSHALL	*Executive Clerk*

THE WORKING STAFF

H. R. SMITH, B. Sc	*Animal Husbandry*
A. T. PETERS, D. V. M	*Animal Pathology*
FREDERICK D. HEALD, Ph. D	*Botany*
F. J. ALWAY, Ph. D	*Chemistry*
A. L. HAECKER, B. Sc. A	*Dairy Husbandry*
LAWRENCE BRUNER, B. Sc	*Entomology*
E. G. MONTGOMERY, B. Sc	*Field Crops*
F. G. MILLER, M. F	*Forestry*
ERWIN H. BARBOUR, Ph. D	*Geology*
G. R. CHATBURN, A. M	*Highway Engineering*
R. A. EMERSON, B. Sc	*Horticulture*
O. V. P. STOUT, C. E	*Irrigation Engineering*
G. A. LOVELAND, B. Sc	*Meteorology*
ALVIN KEYSER, A. M	*Soils*
W. P. SNYDER, M. S	*Supt. Experimental Substation, North Platte*
J. H. GAIN, M. D. C	*Associate in Animal Pathology*
A. F. MAGDANZ, JR., A. B	*Assistant in Animal Husbandry*
L. B. STURDEVANT, A. M	*Assistant in Animal Pathology*
MARTIN NELSON, M. S	*Assistant in Field Crops*
F. E. DENNY, A. B	*Assistant in Horticulture*
S. W. PERIN	*Farm Superintendent*

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*By an act of the Legislature of the State of Nebraska approved and in effect February 15, 1899, the State Treasurer became *ex officio* custodian of the Experiment Station fund on and after July 1, 1899.

TWENTIETH ANNUAL REPORT

EXPERIMENTAL WORK

The work of the Experiment Station for the current year has been confined to the following lines, namely:

Improvement of winter wheat by selection of desirable varieties hardy in the northern and western portions of the State, cross-breeding varieties to combine desirable qualities, selection of individual plants, etc. One hundred and forty new strains of wheat, originated in this way, are now being tested under field conditions. A large number of varieties of wheat are being brought from other States to note the effect of climate on quality and yield.

Promising varieties of oats are added each year, to test in comparison with standard varieties of this region.

Improvement of corn is carried on by selecting varieties and by improving the yield of the most promising varieties by the ear-and-row method of selection. About 400 ears are being tested in this way each year in breeding plats, selecting seed from those which prove superior in yield and desirable qualities. A study is being made of qualities which are correlated with large production.

Improvement of alfalfa seed by selection of individual plants is in progress, 3,000 plants in the nursery having been studied the last three years. Seed is being selected from those plants which present the largest number of desirable characteristics.

Winter barley and winter macaroni wheat are being grown and tested thruout a large region in the State. Experiments are also in progress to determine a more effective method of seed treatment of winter barley for the prevention of smut.

The effect of manure and grass on crop rotation is being studied. using grasses or legumes for three years and grain for four years, in a seven-year rotation; also the effect of fertilizers on soils of known composition, to determine the influence of food material introduced through commercial fertilizers on crop production. A complete series of experiments is in progress, using nitrogen, phosphorus, and potassium.

Methods of determining humus are in progress.

Experiments are in progress to determine the effect and duty of water on the production of crop; also the effect of soil aeration, soluble salts, water supply, and temperature, upon crop rotation and plant development.

Experiments are in progress with potatoes to determine the effect of spraying on blight, the size of seed to use under various conditions, the effect of northern and home-grown seed on production, the effect of tillage and cover-crops on growth and hardiness of orchards.

The Station has investigated numerous plant diseases, including ergot, bud-rot of carnations, bitter spot of the apple, twig girdle of the apple, bacterial blight of wheat and soy bean, and will give its attention to investigation of the cherry shot-hole disease and the cedar apple on the red cedar, looking to the control of these destructive diseases.

Investigation of weeds and weed seeds adulterating the grass seeds sold for commercial purposes has been in progress and will continue.

Investigations are in progress to determine what chemical agents may be applied for artificial bleaching of flour, amount of bleaching agent used, methods of identification of flours bleached by different agents and their effect upon the quality of the flour and the health of the consumer.

Experiments have been completed testing the effect of different kinds of roughness when used with corn in fattening cattle.

Experiments are in progress to determine the effect of different by-products, such as corn-meal, oil-meal, wheat bran, and also alfalfa hay, when used with corn and corn-stover in fattening steers.

Experiments are in progress to determine the influence of food on the strength of bone of growing pigs, using tankage and ground bone in connection with corn for fattening purposes.

A milking machine is in use, to determine its efficiency in comparison with hand milking of dairy cows.

Investigations are in progress to determine the influence of silage upon the cost of butter when fed in connection with alfalfa and a mixed grain ration.

Investigations of loco, cornstalk disease, and malarial fever are in progress.

Investigations are soon to be undertaken to determine forest trees adapted to Nebraska conditions, methods of planting and cultivation, pruning and thinning.

COOPERATIVE EXPERIMENTS

Cooperative experiments are in progress with farmers in the introduction of winter wheat into the northern and western part of the State. In 1900 almost no winter wheat was raised in the northern portion of the State, where in 1906 more than 9,000,000 bushels were harvested. Kharkof and Beloglina wheat are specially being tested in comparison with Turkey Red, the standard variety.

Winter barley is being tested by twenty-five farmers.

One hundred farmers are conducting variety tests of corn to determine what varieties are adapted to their respective regions. This experiment has been conducted for five years and has resulted in enabling the Station to find good yielding varieties for each section of the State. Home-grown seed has uniformly given better results than seed brought from a distance. The use of better-selected and better-bred varieties has always increased the yield. Several hundred farmers are growing macaroni wheat, brome grass, Turkestan alfalfa, emmer, cowpeas, barley, broomcorn, millet, etc.

Cooperative tests of soil fertility are in progress at one point.

In cooperation with the Federal Department of Agriculture, experiments are in progress to improve hard winter wheats and to introduce new crops to this region; also to control apple-scab and codling-moth by spraying; also to study the effect of tillage and rotations on crop production; also in the prosecution of the plant disease survey of the State, and in testing varieties of vegetables.

STATION STAFF

Within the past year a number of changes in the Station staff have taken place. Many of them have become operative since the close of the year ended June 30, 1906.

Mr. Roscoe H. Shaw resigned as Associate Chemist, and Dr. F. J. Alway has been elected Station Chemist and Professor of Agricultural Chemistry.

Professor T. L. Lyon resigned September, 1906, as Professor of Agronomy, and the Department was divided, establishing a Department of Soils and a Department of Field Crops. Mr. Alvin Keyser was elected Adjunct Professor of Soils, and Mr. E. G. Montgomery Adjunct Professor of Field Crops; in charge of both instructional and Station work.

Mr. Martin Nelson has been elected Instructor in Field Crops and Assistant in the Experiment Station.

Mr. A. F. Magdanz, Jr., has been elected Assistant in Animal Husbandry in the Station; Mr. F. E. Denny, Assistant in Horticulture; and Mr. L. B. Sturdevant, Assistant in Animal Pathology.

Mr. G. A. Loveland has been elected Meteorologist of the Station in place of Professor G. D. Swezey, resigned.

Mr. F. G. Miller has been elected Station Forester.

IMPROVEMENTS

An Addressograph mailing machine with 14,000 names has been purchased for facilitating the work of mailing bulletins been made to the plant of the Experiment Station during the current year, although some improvements to the plant for instructional purposes have been made and are in progress. Notable among these is the erection of a building which will be used for instruction in Home Economics in the School of Agriculture.

THE NORTH PLATTE STATION

During the past biennium about $10,000 has been expended for a superintendent's house, horse barn, moving and enlarging the foreman's house, construction of sheds for cattle and hogs, and the construction of about five miles of fence on the Substation farm. The farm has been laid out in permanent plats, about 120 acres of cultivated land being used for plat experiments in crop production on the bench land and 100 acres on the tableland. One hundred acres of land is devoted to alfalfa and to a study of the production of pork upon minimum grain rations. Durum wheats have been compared with local spring varieties, the yield for the last three years being more than double that of the local varieties. In 1906 Velvet Don wheat produced 23.4 bushels. while the local spring variety yielded 10.6. Winter wheat raised upon summer tilled land produced from 40 to 45 bushels per acre, 425 bushels from a 10-acre field. Kharkof wheat was the highest yielding variety, producing 45.7 bushels. This wheat has been sold for seed and distributed thruout the region. Kherson oats, Sixty-Day oats, and Texas Red have all produced good yields under ordinary crop conditions, producing double the yields of the local varieties. In 1906 Kherson oats yielded 47 bushels, while the local oats yielded 24 bushels per acre under like conditions. Barley has produced from 12 to 60 bushels per acre, depending on the condition of the land. The local variety is superior to those introduced. Sorghum has yielded from 3 to 4½ tons per acre.

Moisture.—The conservation of moisture thru summer tillage has always given a good crop where land under ordinary tillage failed. Summer tillage of land traps the water, absorbs the rains as they fall and prevents their running off. It checks evaporation from the soil by keeping a surface mulch on the land. It saves the rainfall of one year to grow a crop the next year. No lesson so much needs to be taught in the semiarid country as that tillage will conserve moisture, that this moisture must be stored before the drought begins, and that the production of crops should not be left to the accident of seasonable rains.

Experiments with swine have been conducted on a rather large scale, more than 300 hogs being under experiment, to determine the relative profit of different amounts of grain in connection with alfalfa pasture and alfalfa hay. Light grain rations have given a larger production of pork from a given weight of grain, hogs requiring from 150 to 400 pounds of grain under different methods of feeding and different conditions of the animal. A medium grain ration of 2 pounds per head daily for each 100 pounds of live weight of the animal, finishing these hogs on a full ration after they have reached a weight of 150 pounds, has proved profitable. A full ration of grain on pasture has always produced the largest profit per day under conditions which have existed since these experiments were in progress.

Experiments are in progress in wintering cattle to determine the kind of roughness most economical. Alfalfa hay, prairie hay, sorghum hay, and a combination of alfalfa with sorghum, also of alfalfa with prairie hay, have been used.

Reports of experiments in crop production and in feeding cattle and swine are ready for publication.

Cooperative experiments with the Federal Department of Agriculture are in progress in the effect of tillage and of crop rota-

One hundred and thirty or more Institutes will be held during the year closing June 30, 1907. Fifty Institutes have been refused for the year 1906-07, on account of lack of appropriations. Six thousand dollars per year is appropriated from the general fund of the State for this extension work.

Various agricultural societies meet with the University each year, including the State Board of Agriculture, State Horticultural Society, State Dairymen's Association, State Live Stock Breeders' Association, State Swine Breeders' Association, State Veterinary Medical Association, State Poultry Association, and Duroc-Jersey Swine Breeders' Association. About 1,500 people were in attendance at the meetings held in January, 1907.

PUBLICATIONS

The mailing list has been revised, reducing the regular list within the State to about 12,600. It still requires an edition of from 20,000 to 25,000 bulletins for distribution. The Annual Report, containing the financial statement and a resume of the experimental work of the Station, is published in an edition of 5,000 copies. The publications of the Station since those named in the last Annual Report are as follows:

Nineteenth Annual Report. Presented to the Governor February 1, 1906. 5,000 copies.

Bulletin No. 92 (Vol. XVIII, Art. III). Cover-crops for Young Orchards. By R. A. Emerson. Distributed June, 1906. 20,000 copies.

Bulletin No. 93 (Vol. XVIII, Art. IV). Cattle Feeding Experiments. By H. R. Smith. Distributed June, 1906. 25,000 copies.

Bulletin No. 94 (Vol. XIX, Art. I). Fattening Pigs on Corn and Tankage. By E. A. Burnett, Director. Distributed October 6, 1906. 25,000 copies.

Press Bulletin No. 21. A Good Oat for Nebraska. By T. L. Lyon. Distributed February 26, 1906. 5,000 copies.

Press Bulletin No. 22. Malarial Fever in Horses. By A. T. Peters. Distributed July, 1906. 5,000 copies.

Press Bulletin No. 23. Ergot and Ergotism. By F. D. Heald and A. T. Peters. Distributed October 16, 1906. 20,000 copies.

ACKNOWLEDGMENTS

The various railroads of the State have furnished considerable transportation to assist in carrying on experimental work located outside of Lincoln. If this transportation is to be cut off by action of the State law, appropriations to pay for needed transportation for experimental purposes should be made by the State. This will particularly affect the investigation of plant and animal diseases, the work of the Substation at North Platte, and the Farmers' Institutes. The cost of this transportation would exceed $6,000 for the biennium.

The agricultural press, especially those papers located within the State, have shown their appreciation of the work of the Experiment Station by giving a liberal amount of space to the experimental work reported and in every way facilitating and extending the usefulness of the Experiment Station.

THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA

FINANCIAL STATEMENT

RECEIPTS (HATCH FUND)

Received by the state treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1906, as per act of Congress approved March 2, 1887........................$15,000 00

EXPENDITURES

Salaries		$9,143 06
Labor		2,043 95
Publications		875 40
Postage and stationery		562 37
Freight and express		49 45
Chemical supplies		116 62
Seeds, plants and sundry supplies		406 06
Feeding stuffs		809 48
Tools, implements and machinery		233 65
Furniture and fixtures		83 10
Scientific apparatus		270 24
Live stock		103 11
Traveling expenses		120 11
Contingent expenses		15 00
Buildings and repairs		168 40
	$15,000 00	$15,000 00

RECEIPTS (ADAMS FUND)

Received by the state treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1906, as per supplemental act of Congress approved March 16, 1906	$5,000 00	

EXPENDITURES

Salaries		$99 95
Labor		483 50
Postage and stationery		4 25
Freight and express		21 44
Chemical supplies		353 68
Seeds, plants and sundry supplies		30 70
Library		48 93
Tools, implements and machinery		307 16
Furniture and fixtures		70 00
Scientific apparatus		3,513 19
Traveling expenses		67 20
	$5,000 00	$5,000 00

SUPPLEMENTARY STATEMENT

RECEIPTS

Moneys received by the state treasurer from other sources than the United States, for the use and benefit of the Experiment Station, for the year ended July 31, 1906.

Balance, July 31, 1905	$1,818 76	
Sales of stock, produce, etc	14,575 67	

DISBURSEMENTS

Salaries, temporary services		$929 97
Labor		1,167 77
Publications		11 74
Postage and stationery		73 69
Freight and express		241 03
Chemical supplies		13 30
Seeds, plants and sundry supplies		558 65
Feeding stuffs		2,665 38
Tools, implements and machinery		318 87
Furniture and fixtures		92 70
Scientific apparatus		359 90
Live stock		2,642 43
Traveling expenses		91 85
Buildings and repairs		477 51
Balance, July 31, 1906		6,749 64
	$16,394 43	$16,394 43

FARMERS' INSTITUTES

Legislative appropriation of 1905 (April), from the state general fund for two years ending March 31, 1907	$12,000 00	
Expenditures to November 30, 1906, for superintendence, clerical services, lecturers' expenses and services, printing, supplies		$6,631 84
Balance, November 30, 1906		5,368 16
	$12,000 00	$12,000 00

SUBSTATION (NORTH PLATTE)

Legislative appropriation of 1905 (April), from the state general fund for two years ending March 31, 1907	$20,000 00	
Expenditures to November 30, 1906, for superintendence, labor, live stock, feed, seeds, tools, machinery, permanent improvements and general supplies		$20,000 00
	$20,000 00	$20,000 00

Respectfully submitted,

J. S. Dales,

Lincoln, Nebraska, January 23, 1907.

Financial Secretary.

V. 4616
(Box on sh.)

THE UNIVERSITY OF NEBRASKA

TWENTY-FIRST ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF

NEBRASKA

FEB. 15. 1869

PRESENTED TO THE GOVERNOR JANUARY 29, 1908

LINCOLN, NEBRASKA
U. S. A.

V. 4616

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LETTER OF TRANSMITTAL.

THE UNIVERSITY OF NEBRASKA.
AGRICULTURAL EXPERIMENT STATION.

To His Excellency, George L. Sheldon, Governor of Nebraska:

SIR: In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Twenty-first Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
Director.

January 29, 1908.

GOVERNOR'S CERTIFICATE.

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT,
LINCOLN, JANUARY 29, 1908.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR: I hereby acknowledge receipt of the Twenty-first Annual Report of the Nebraska Agricultural Experiment Station.

GEORGE LAWSON SHELDON,
Governor.

THE OFFICIAL ROSTER OF THE STATION.

THE GOVERNING BOARD (THE REGENTS OF THE UNIVERSITY)

Hon. Charles S. Allen, Lincoln, President	Term expires 1910
Hon. William G. Whitmore, Valley	Term expires 1910
Hon. Frederick H. Abbott, Aurora	Term expires 1912
Hon. Victor G. Lyford, Falls City	Term expires 1912
Hon. Charles B. Anderson, Crete	Term expires 1914
Hon. George Coupland, Elgin	Term expires 1914

J. S. Dales, Financial Secretary.*

THE EXECUTIVE COMMITTEE.

Charles S. Allen
E. Benjamin Andrews
E. A. Burnett

THE STATION OFFICERS.

E. A. Burnett, B. Sc	Director
W. W. Marshall	Executive Clerk

THE WORKING STAFF.

H. R. Smith, B. Sc	Animal Husbandry
A. T. Peters, D. V. M	Animal Pathology
Frederick D. Heald, Ph. D	Botany
F. J. Alway, Ph. D	Chemistry
A. L. Haecker, B. Sc. A	Dairy Husbandry
Lawrence Bruner, B. Sc	Entomology
E. G. Montgomery, B. Sc	Field Crops
Frank J. Phillips, M. F	Forestry
Erwin H. Barbour, Ph. D	Geology
G. R. Chatburn, A. M	Highway Engineering
R. A. Emerson, B. Sc	Horticulture
O. V. P. Stout, C. E	Irrigation
G. A. Loveland, B. Sc	Meteorology
Alvin Keyser, A. M	Soils
W. P. Snyder, M. S.	Superintendent Experimental Substation, No. Platte
J. H. Gain, M. D. C	Associate in Animal Pathology
A. F. Magdanz, Jr., A. B	Assistant in Animal Husbandry
L. B. Sturdevant, A. M	Assistant in Animal Pathology
Stella A. Hartzell, A. M	Assistant in Chemistry
E. M. Little, B. Sc	Assistant in Dairy Husbandry
Martin Nelson, M. S	Assistant in Field Crops
F. E. Denny, A. B	Assistant in Horticulture
S. W. Perin	Farm Superintendent

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TWENTY-FIRST ANNUAL REPORT.

EXPERIMENTAL WORK.

The work of the Experiment Station for the current year has been as follows:

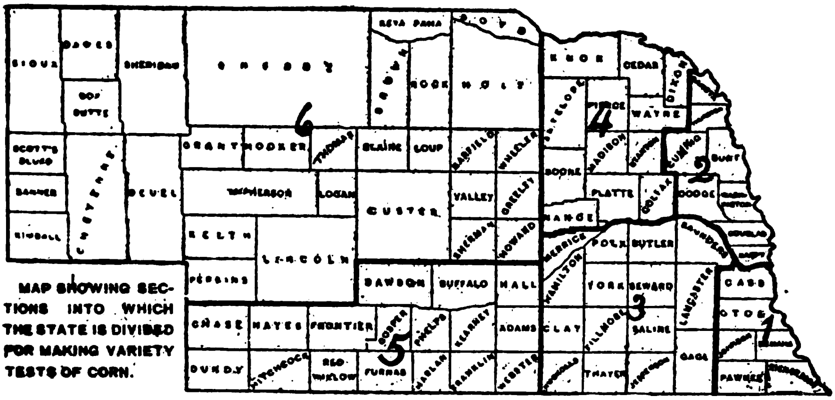
The lines of investigation in the Experiment Station are of two classes: First, those which are technical and scientific in their character, endeavoring to discover scientific principles which may have a bearing on practical farm problems; second, the adaptation of scientific principles already worked out, to the practical needs of the farmer.

All investigations carried on under the Adams act are, according to limitations of Congress, confined to strictly scientific questions or the accumulation of knowledge which does not now exist and which when worked out may have a bearing upon practical agricultural questions. The other funds of the Experiment Station, such as the Hatch fund appropriated by the federal government and state appropriations, are available for the less technical lines of investigation which may have the most immediate and beneficial influence on the general farm practices of the state.

The work which this Station has done in the extension of the winter wheat area of the state has resulted in very greatly increased areas of wheat, carrying this extension first to the southwest, then to the northeastern section of the state, where production has increased more than 9,000,000 bushels in the last seven years, and more recently extending winter wheat production into the northwest area of the state thru the work of the Substation at North Platte, where the yields of winter wheat upon summer tilled land have exceeded the average yields of wheat in the eastern counties of the state under the methods of production in common use.

Under the Adams fund, investigations have been carried on in the bleaching of wheat flours to determine whether the processes now in use by the millers have a deleterious effect on the health of persons consuming such flours. These investigations are reported in Bulletin No. 102. The general subject of wheat flours is further being investigated to determine the cause of the strength of flour or those qualities which tend to produce a large and well-formed loaf and make the flour desirable from the standpoint of the miller. Considerable controversy exists among scientific men at the present time as to the true cause of strength in flour, and until this can be determined it is impossible to determine what qualities in wheat should be developed in order to produce the most desirable wheat from the miller's standpoint. In connection with this work the Experiment Station is developing a large number of strains or subvarieties of Turkey Red wheat with the expectation that the yield of some of these wheats will considerably exceed the yield of the Turkey Red wheat in common use and that the chemical composition of this wheat will be such as to make it the most acceptable from the miller's standpoint.

The work of the Experiment Station in promoting the corn industry of the state has been large and efficient. Within the last five years, under the stimulus and advice of the Experiment Station, more accurate and exact study of the improvement of corn has been made than in all the years which preceded. The agitation for the selection of better seed has resulted in giving very much greater attention to this important question. The discussion of soil fertility, the rotation of crops, and of tillage to conserve moisture, have all tended to modify the practice of the average farmer and very greatly to improve the methods of the men who had previously given this subject special study. This investigation has tended to unify the general opinion regarding varieties best adapted to localities and to prove by careful investigation that certain varieties were superior to others which had commonly been grown. Five years' work has been done to determine what two varieties of corn were best adapted to each of the different corn regions of the state. The result of these investigations has shown that in the eastern section of the state, with twenty-seven men cooperating, the average yield of the best two varieties in each county for five years has been 54 bushels per acre, the average yield of all corn in the same counties being 36 bushels per acre. The selected varieties produced an average of 18 bushels per acre more than the average of the county. This is good evidence to show that if good varieties are used and the average standard of farming is brought up to that of the best farmers in each neighborhood, an average increase of 15 to 20 bushels per acre would result. The state has been divided into six different corn districts, according to a map shown herewith. The tests of cooperative farmers assisting in this investigation have shown:



MAP SHOWING SECTIONS INTO WHICH THE STATE IS DIVIDED FOR MAKING VARIETY TESTS OF CORN.

In Section 1, Reid's Yellow Dent gave best average yield for five years, 1902 to 1906 inclusive. Hogue's Yellow Dent gave next best yield. These are both yellow varieties. The two most promising white varieties were Nebraska White Prize and Silver Mine. Results obtained during the past three years, however, indicate that Chase's White Dent may be the best white variety.

In Section 2, Reid's Yellow Dent has given best yield for five years, and Hogue's Yellow Dent second best. The two best white varieties are Silver Mine and Nebraska White Prize.

In Section 3, Hogue's Yellow Dent has given best yield and Golden Row second best. Silver Mine and Chase's White Dent are to be recommended for white varieties.

In Section 4, Golden Row and Reid's Yellow Dent have given best results as yellow varieties, and Nebraska White Prize and Silver Mine as white varieties, tho in many cases the two white varieties have not matured well.

In Sections 5 and 6 we have not been able to secure sufficient information to determine certainly the varieties best adapted. A collection of native corns was made last year from forty different farmers, and the work will be considerably extended in the future. At the North Platte Station for the years 1905 and 1906, calico corn gave yields of 39.3 bushels and 52 bushels respectively, with an average of 45.6 bushels. Reid-Hogue cross yielded 39.3 and 47.8 bushels, with an average of 43.5 bushels. Improved Leaming yielded 37.1 bushels and 47.4 bushels respectively, with an average of 42.4 bushels. Silver Mine, a white corn, yielded 39.3 bushels and 52.2 bushels, with an average of 45.9 bushels. The calico corn above mentioned will probably continue to hold a leading place among the varieties grown in western Nebraska, and the other varieties mentioned are liable to change with more extensive tests.

Breeding work with corn at the central Station covering five years' investigation shows the average of such corn to be nine bushels per acre more than the check plats from which this corn originated, these check plats having been grown upon the land in the same state of fertility and with the same conditions of tillage as the corn which had been selected for increased yield and higher producing types. The final distribution of these improved varieties cannot but have a large beneficial effect upon the corn-growing industry in the regions to which they are adapted.

Under the Adams fund investigations, we are studying the relation of leaf area to the water used in the growth of the corn plant. It is proposed to determine by means of potometers the amount of water used by different types of the corn plant, and later to determine which type of plant is best adapted to Nebraska conditions, which has the greatest yield, and which the greatest ability to withstand drought. It is believed that this investigation will determine what particular characteristics of the corn plant enable it to reach the highest development and produce the greatest yield under the conditions which exist in this state. When these facts have been determined, the development of corn having the proper characteristics will materially increase the yield per acre and have an economic bearing upon the production of the state.

An investigation of the soils of the state is in progress, to determine roughly the different soil regions of the state as indicated by the different geological formations from which these soil regions are derived. This line of investigation should be continued until accurate maps of these soil regions are available, as the character of the soil in the different regions of the state will influence the character of the agriculture which is practiced. Our neighboring states to the east are spending large sums of money at the present time in working out these soil regions for their respective states and have already found that the knowledge thus obtained has made it possible to operate the lands in the different areas more profitably than could be done without this exact knowledge regarding the constituents of which the soil is made up.

Limited experiments have been carried on to determine the influence of commercial fertilizers upon the wheat crop in the older sections of the state. These experiments so far indicate that soils which are declining in their productiveness are lacking in nitrogen, but are not lacking in the other elements of plant food necessary to a fertile soil. Nitrogen is readily supplied by the application of barnyard manure, or by seeding lands down to grass, alfalfa or clover, and permitting a rest from grain production for a period of years, after which these lands can again be used for growing grain with very greatly increased production. All of the investigation which has been carried on relative to the management of soils points conclusively to the fact that rotation of crops is necessary to secure the largest yields and the largest profits from the land; that periods of grain growing must be interspersed with periods during which the land is in grass or leguminous crops like clover and alfalfa, and that the maintenance of the fertility of the soil in any region of high-priced land is the key to successful agriculture.

Studies in soil tillage have shown that water should be conserved or stored up in the soil when there is no crop upon the land, so that it may be used by the crop later on. Especially in the western section of the state it is impossible to depend upon the rainfall of the growing season to supply the water necessary to mature a crop. While timely rains may supply an abundance of water, there is likely to be a period during the growth of any crop when soil water is deficient. If crop production is carried into the region where it has not before been generally successful, it will be largely thru the introduction of methods which store water in the soil before the crop is sown, to assist in maturing the crop during the latter period of its growth. Since these principles apply to all agricultural regions, and since shortage of soil water is likely to occur in the regions of most abundant rainfall, it is essential that our farmers understand the principle of conserving soil water and use those methods, even in the regions of most abundant rainfall. Such methods act as an insurance in crop production and once understood can be applied to the land without largely increasing the cost of farm operations.

The relation of humus (total organic matter) in the soil to nomical beef production. Two hundred and ninety-four cattle have been used in these experiments, which have conclusively shown that the character of the ration is an essential factor in economical production; that economical rations containing the food nutrients which are adapted to the use of the animals fed may be simple and may be grown entirely upon a Nebraska farm. Roughly speaking, the essential point in food nutrients is that there shall be a proper relation between what are known as the protein constituents of the food and the carbohydrate and fat constituents of the food; in other words, between the albuminoid material in the food and the starches, sugar, fat and crude fiber in the food. These proportions do not need to be determined with mathematical accuracy, but can be determined with sufficient accuracy to give economical results by any farmer who understands something of the nature and character of these different foods. For example, there is a certain class of foods grown on the farm which will supply the protein requirements in fattening cattle. These foods are, first, alfalfa hay; second, clover hay; followed by oats and bran as useful but not so economical foods at their present prices. This makes the range of protein foods grown on the Nebraska farm extremely narrow, and, when these foods cannot be supplied from the farm, experiments have shown that it is economical to purchase in the markets commercial foods which supply these protein requirements. The commercial foods most commonly used are linseed-meal, cottonseed-meal, and possibly those protein foods which are the by-products of the starch factory. All of the experiments of our Station have shown that protein foods can be produced upon the farm in the form of alfalfa hay at about half the cost of such food constituents when purchased in the form of commercial foods. The farmer who takes advantage of this knowledge and grows his protein upon the farm accomplishes the double result of making large profits upon his cattle feeding operations and of very greatly increasing the productiveness of his soil by the same operation.

It has been shown by experiments that more protein nutrients are supplied by alfalfa hay when it is used as the entire roughness of feeding steers than is necessary for their use, and that it is possible to utilize prairie hay, corn stover and unhusked corn which has been shocked at the proper time so as to make these forms of roughness very much more valuable than they could be made without the use of alfalfa hay in feeding operations.

It has been shown that the use of alfalfa hay and corn-stover fed in connection with shelled corn will produce a liberal profit in beef production where the use of prairie hay and shelled corn has given an actual loss in feeding operations.

It has been shown that younger cattle, especially calves and yearlings, are more dependent upon protein nutrients found in alfalfa hay or linseed- or cottonseed-meal than older cattle, and that the farmer, when he attempts to feed calves or yearling steers, will find it more necessary to maintain the proper balance between protein and nonprotein food constituents than in feeding older and mature cattle.

In fattening pigs upon corn as the principal ration, it has been found that the use of tankage, a by-product of the packing house, has increased the rate of gain and decreased the cost of production where the percentage of tankage fed was about five per cent of the total ration; that a larger per cent of tankage did not greatly increase the rate of gain, and in some instances did increase the cost of gains to a point above the cost where corn alone was fed. These experiments show, as do the experiments with cattle, that there should be a certain relation between the protein and nonprotein constituents of the food of any animal, and that it is as possible to increase these protein constituents beyond the point of profitable production as it is to limit them below the point of profitable production. In other words, it is necessary to are not so dependent upon protein in other food constitutents as those which do not have alfalfa pasture. The tests at the central Station, however, indicate that alfalfa pasture does not furnish a sufficient amount of protein for economical production when corn makes the balance of the ration, but that mixed grains with alfalfa pasture overcome the necessity for feeding tankage when they can be supplied at a lower cost. The results of experiments at the western Station have indicated that corn and alfalfa hay or such mixed grains as corn, barley, speltz, and alfalfa hay furnish cheaper protein nutrients than were supplied in tankage.

Experiments are in progress which are of very great interest to the breeder of pure-bred stock, indicating that the strength of bone in pigs may be very materially increased by the use of tankage, of ground bone, or of skim-milk fed with grain in growing pigs. Three years' work has been done on this problem and the results have uniformly shown a marked increase in the strength of bone where tankage or ground bone has been fed. This information is valuable because the character of the feed used in pork production tends strongly to produce a bone of low tensile strength and a small percentage of mineral matter, while the heavy weights developed in the young pig tend to produce animals which do not stand properly on their feet. The experiments above mentioned indicate that by proper methods of feeding and care in the selection of individuals for breeding purposes the tendency toward bad feet and legs may largely be overcome.

Experiments at the western Station reported in Bulletin No. 99 show that even in western Nebraska where alfalfa is abundant and grain of moderate price, liberal grain rations produce larger profit and more economical results than are secured by growing hogs largely upon alfalfa pasture. These experiments indicate that where alfalfa hay is fed and corn is valued at 35 cents per bushel, barley is worth about 24 cents per bushel and emmer about 19 cents per bushel, four bushels of barley being equal in value to five bushels of emmer. It is not probable that a second experiment would exactly verify these figures, altho we should expect it to reasonably approximate these results.

The work of the Experiment Station in the care and management of dairy cattle has shown that the value of the individual members of the herd can only be determined by individual milk and butter fat records. Such records will show great variation in the value of the different animals and will serve as a guide in the building up of an efficient herd.

Cows vary from year to year in their butter fat production. The good cows in this herd have been inclined to give large yields year after year, while the poor ones have always been relatively low. It has been found that as a rule the variation in milk flow in individual cows from year to year is due to length of lactation period and rest before freshening. A long period favors a large milk production. The cows which have given large annual yields have all been persistent milkers and have continued milking to within four or six weeks of the next calving time.

A study of the cost of butter fat production has shown that the amount of milk and butter fat produced depends upon the dairy capacity of the animal and the amount and quality of the ration used. Cows of a decided dairy type will return the greatest profit in milk and butter when fed to their full capacity. The average cost of feeding a dairy cow as shown by these records is about $30 per year, and the total value of butter fat of the Station herd is about $70 annually per cow: leaving an average of about $40 for labor and profit in addition to the value of the skim-milk and the value of the calf.

With the prices for forage and grain which have prevailed at the Experiment Station for the last four years, the cost of butter production can be reduced about 20 per cent by the use of silage as a part of the ration. This result is obtained by reducing the cost of feed and by materially increasing the average yield of does not fit into their method of dairying and that the original cost is too high. It has been found at the Station that even with the use of alfalfa hay, which is a most excellent ration for butter production, the cost of butter could be still further lowered by the use of silage as a part of the ration. The Station is firmly convinced that all dairymen milking twenty-five or more cows can profitably incur the expense of a silo under such conditions as now exist in eastern Nebraska.

The Experiment Station has published a bulletin on "The Fat Testing of Cream," which is being used as a standard method by the Dairy and Food Commissioner of the state.

SPRAYING APPLE ORCHARDS.

During the summer of 1906, spraying demonstrations were conducted in six counties in Nebraska, the United States Department of Agriculture cooperating, the purpose of the work being to control the apple scab and codling-moth and to determine whether the advantages of such spraying would pay the cost incurred. These demonstrations were continued during the summer of 1907, with the result that a very superior quality of fruit was produced upon the trees which were sprayed. Records made at the end of the season from the entire crop of 37 sprayed trees and 39 unsprayed ones in different orchards, including observations on more than 110,000 fruits, showed 22 per cent of wormy apples on the sprayed trees and 46 per cent on the unsprayed ones. Of the sprayed fruits 6 per cent and of the unsprayed fruits 38 per cent were scabby.

During the fall, the foliage of the sprayed trees was much healthier than that of the unsprayed ones. In many cases from 50 per cent to 75 per cent of the foliage of unsprayed trees was on the ground early in October and in some instances the trees were almost completely defoliated at that time. At the same time the leaves of the sprayed trees were bright green and comparatively free from fungus diseases.

The crop was gathered from 205 sprayed trees and 71 unsprayed trees. The average yield of the sprayed trees was 8.4 bushels per tree and of the unsprayed trees 6.6 bushels per tree. When sorted into merchantable and unmerchantable fruit, 8 per cent of the sprayed fruit and 23 per cent of the unsprayed fruit were unmerchantable. The total value per tree of the unsprayed fruit was $0.80 and of the sprayed fruit $1.87. The cost of spraying was 21 cents per tree. The profit of the sprayed trees over the unsprayed trees was 86 cents per tree.

POTATO EXPERIMENTS.

Experiments to determine the effect of mulching potatoes as against cultivation have been carried on for a number of years. Potatoes grown under a mulch have been of poorer quality for table purposes than those grown under cultivation, but have been superior for seed purposes. Medium-sized seed pieces, about one-quarter of a tuber, are superior to smaller sized pieces when planted in hills so that the amount of seed equals from 15 to 20 bushels per acre. Potatoes planted 4 inches deep gave larger yields than those planted either shallower or deeper than 4 inches. The results of this work are reported in Bulletin 97.

The Station has recently investigated the subject of loco poisoning in horses and expects to present a detailed report of its work in the appendix to this Report.

The study of cornstalk disease has been systematically carried on in three counties of the state, in an effort to determine the prevalence of the disease, the methods of treatment, if any, which were successful in lessening the loss, etc. The result of this work is reported in Press Bulletin No. 27. No information tending to prevent the loss of cattle turned upon stalk fields has been developed in this investigation.

An investigation of the seed of cheat, meadow fescue, and brome grass by the Station has shown that a large amount of cheat seed is annually sold as either brome grass or meadow fescue by persons who ignorantly or otherwise have misrepresented the variety of seed for sale. Press Bulletin 25 deals with this subject. The Experiment Station is establishing, in cooperation with the United States Department of Agriculture, a seed testing laboratory, where all samples of grass seed and other seeds sent to the Station will be examined free of cost. The per cent and quality of impurities in seed samples will be reported, as well as the per cent of germination.

The Station has recently investigated a new disease which has been somewhat prevalent in Nebraska and a number of other states during the last few years, known as the bud-rot of carnations. This disease has been proved by the Station to be due to a definite species of fungus, *Sporotrichum anthophilum* Peck, which has, associated with it, a new species of mite, *Pediculoides dianthophilus* Wolcott, as a constant accompaniment. The disease affects the buds of carnations in various stages of maturity and rots the petals and other flower parts, interfering with the normal opening of the flower. The disease is successfully treated by special care to remove from the greenhouse all material favoring its propagation, by keeping the moisture down to the minimum necessary for the healthy growth of the plants, and by picking off and burning all the diseased portions of any plant. Benches should be gone over at least every other day until the disease is thoroly under control. The results of this investigation are published in Bulletin 103.

COOPERATIVE EXPERIMENTS.

Cooperative experiments are in progress with farmers of the state in testing varieties of corn adapted to different regions, in extending the winter wheat area of the state, in introducing winter barley to determine its hardiness and production, and in spraying demonstrations with apple orchards.

In cooperation with the federal Department of Agriculture, experiments are in progress to improve the quality and production of hard winter wheats, to introduce new crops into the region, to control apple scab and codling-moth by spraying, to study the effect of tillage and rotations on crop production, to study alkali-resistant crops, testing varieties of sweet corn, and in the prosecution of the plant disease survey of the state.

THE NORTH PLATTE SUBSTATION.

WHEAT.—Systematic experiments have been carried on in the growth of winter wheat, with the purpose of extending the winter wheat area still farther to the west and north. Most of the winter wheat grown on the Station farm to date has been upon summer tilled land. In the summer of 1906, Turkey Red wheat produced from 31 bushels to 44 bushels per acre. The yield for the year 1907 upon high table-land which had been summer tilled varied from 56 bushels to 60 bushels per acre. Nine acres of land on the bench or second bottom about 200 feet lower than the high table yielded about 30 bushels of rye in 1906, was plowed and sown to wheat, and produced 41 bushels per acre in 1907. It would seem that the essential thing in successfully growing winter wheat in Lincoln County and farther west is to secure a good seed bed with sufficient moisture to give a good fall growth. Spring weather conditions will, of course, have much influence on the crop, but if sufficient moisture has been stored in the soil in advance of sowing the crop, this acts as an insurance against winter and spring drought. In the region of the Substation farm, wheat sown about September 15th upon land with plenty of moisture present has secured a sufficiently heavy fall growth.

While winter wheat has been phenomenally successful at the Substation, the durum wheats have given satisfactory yields and have greatly extended the wheat area of western Nebraska and eastern Colorado and Wyoming. The yields of durum wheat at the Station farm have averaged about 18 bushels per acre for the three years of 1904, 1905, and 1906, while local wheat for the same years on the same land yielded but 7.2 bushels. In 1907 the yields were, for durum, 17 to 33 bushels, and for local spring wheat about the same. The cold, freezing weather in spring was unfavorable to the durum varieties.

OATS.—The oat crop has given fair yields where early varieties have been raised. The Kherson oat has taken the lead at this Station, tho two other varieties have yielded nearly as well. The yield of Kherson oats for three seasons, 1904, 1905, 1906, has been from 24 bushels to 52 bushels, of Texas Red oats for the same period from 29 bushels to 43 bushels, of Sixty Day oats for the same period from 20 bushels to 48 bushels.

Barley.—Barley has been quite universally successful as a spring grain, and emmer fairly successful.

Rye.—Rye has given good yields and has furnished a most excellent pasture for brood sows in winter and in early spring before alfalfa is ready to pasture. It has then gone on and produced a fair yield of grain if not pastured too heavily in winter.

Corn.—Experiments with corn have shown that those varieties which have been grown in the region are generally best adapted to use, even tho they have not been bred and selected for the highest types. Only the earlier of the introduced varieties will ripen at this altitude. In 1905 the five leading varieties produced from 36 bushels to 39 bushels per acre. In 1906 the five leading varieties produced from 47 bushels to 52 bushels. Three years' work would indicate that calico corn is the safest variety for the general farmer to raise in this region. There are doubtless several other satisfactory varieties of the smaller sort. Large varieties, like Hogue's Yellow Dent, Silver Mine, and Hogue-Reid cross, have ripened in favorable seasons, but cannot be considered safe varieties for this region.

Careful tests are in progress with wheat, oats, barley, rye and corn to determine the most desirable rate of seeding, time of seeding, preparation of the seed bed, cultivation, and effect of manures on the yield and quality of crop.

Alfalfa.—About 100 acres of alfalfa is growing on the Substation farm, partly on the table and partly on the bench land or second bottom land. The alfalfa on the bench has produced three crops of hay each year and in addition has pastured about eight pigs per acre thruout the growing season, giving yields not far different from the high-priced lands in eastern Nebraska. The alfalfa on the table-land has varied greatly in yield, dependent on seasonable rains. It has always produced one good crop of about one ton of hay per acre, and a second crop, not so heavy, some time during the season. When rainfall has been abundant in July, this second crop has come on early and made a good yield, but where the rainfall has been scant in July and following months the second crop has been very light, showing evidence that there was little or no reserve moisture in the soil available for the growth of the plant altho there was sufficient to keep the plant alive until moisture for further growth was supplied. No difficulty has been experienced in getting a stand of alfalfa by sowing at the time the spring rains begin on land thoroly prepared. The Station hopes to produce alfalfa seed on the table-lands and thus introduce a very profitable crop for this region.

BROME GRASS.—The Substation has about thirty acres of brome grass growing and has found it to be a valuable grass, standing climatic conditions perfectly and making a good growth. It has not yet been largely used for pasture, the purpose for which it has proved best adapted in other localities.

ANNUAL FORAGE CROPS.—Annual forage crops like cane and Kafir corn have given abundant yield. When sown thick with a press drill, they make the finest and best quality of hay, but produce more seed and somewhat better growth in dry weather when planted in double drills with about 36-inch spaces between the double rows and cultivated like corn. Yields of dry forage from cane have varied from about two tons per acre to as high as six or seven tons in the season of 1907. Limited experiments have indicated that Kafir corn is more palatable for cattle than cane.

DRY LAND FARMING.—The experiments in dry land farming

ALKALI SOILS.—The work in alkali investigations covers 63 tenth-acre plats on a 5-acre tract of land leased by the United States Department of Agriculture. The objects sought are the determination of the relative resistance to alkali of various grain and forage crops, the development by selection of greater resistance to alkali in these, the effect of a corrective such as gypsum, and the effect of cultivation and of manure in preventing the injurious effect of alkali, the United States Department of Agriculture cooperating.

TREE PLANTING.—The work in growing trees embraces tests of varieties, spacing, mixtures, pruning and cultivation. Ten acres are being planted on "bench" land, ten acres on "table"-land and five acres in canyons, the United States Department of Agriculture cooperating.

ORCHARD PLANTING.—In the spring of 1907 about 100 fruit trees were planted of hardy varieties of apple, peach, plum and cherry. These trees are being given thoro cultivation to determine their hardiness, production and adaptability to the western regions of the state. It is proposed in 1908 to plant a number of hardy ornamental trees and shrubs to determine their suitability for planting on western farms.

GROWING HOGS.—Experiments in growing hogs on alfalfa and the grain commonly produced in the region have been in progress since the establishment of the Station. It has been shown that a light grain ration is not most economical for growing pigs unless under peculiar circumstances where alfalfa is abundant and grain very high priced and where the market conditions favor holding the hogs.

It seems probable that two or more pounds of corn daily for each hundred pounds weight of hogs is more profitable than a lighter ration. A heavier ration is desirable for the finishing period, probably between three pounds daily per hundred and a full grain ration.

Mature animals, like brood sows, after weaning pigs will gain about one-half pound per day on alfalfa without grain.

To fattening hogs that have access to alfalfa hay, corn at 35 cents, barley at 24 cents, and emmer at 19 cents per bushel have given about equal results.

It has been shown that the cost per pound of gain is not a reliable criterion of profit. A cheap gain may be so slow as to be unprofitable. Time, labor, investment and risk should be considered when reckoning profits.

Alfalfa in almost any form may be fed with profit to hogs so long as it does not make too large a proportion of the ration. When cut and fed as one-quarter of the ration with ground corn, it materially reduced the cost of gains and increased the profits.

CATTLE FEEDING.—One test has been made to determine the most economical rations in wintering cattle, taking the calf at weaning time and growing him until he is past two years old and ready for the feed lot. Five lots of calves were selected in the fall of 1905 and fed, Lot 1, alfalfa hay; Lot 2, prairie hay; Lot 3, cane; Lot 4, alfalfa and prairie hay; Lot 5, alfalfa and cane. Two pounds of grain was fed daily to each calf during the first winter. The gains made by the calves fed alfalfa hay, or alfalfa and either prairie hay or cane, were not far from 140 pounds each in the four months. The gains on alfalfa hay were 76 pounds and on cane 46 pounds for the same time. The summer gains following did not equalize these differences, so that the lots did not go into the second winter with even weights. No grain was fed the second winter, and the lots were changed so that those receiving the poorest ration the first winter should receive the best ration the second winter. Again the second winter the large and the cheap gains were made on alfalfa hay either alone or combined with prairie hay or cane. Prairie hay

To continue this study of the effect of alfalfa on the growth of animals, thirty weanling colts have been purchased and put on feed, some to be grown entirely on alfalfa hay and alfalfa pasture, others on alfalfa hay and prairie pasture, and still others on prairie hay and prairie pasture, to determine the effect of alfalfa on the weight and the quality of the horses at maturity.

THE STATION STAFF.

Within the past year the following changes in the Station staff have taken place:

Professor F. G. Miller has resigned as Forester, and Professor F. J. Phillips has been employed, beginning September 1, 1907.

Mr. E. M. Little has been added to the staff as Assistant in Dairying.

Miss Stella A. Hartzell has been made Assistant in Chemistry.

IMPROVEMENTS.

The last Legislature appropriated $100,000 for improvements at the University farm. This money is largely used for the development of agricultural education, but the Experiment Station benefits largely from the buildings and the equipment made available under this appropriation. A new heating plant has been completed, with two 350 horse power high pressure boilers, and all buildings on the University farm requiring heat have been connected with this new system. A judging pavilion, offering facilities for judging live stock and grain, is approaching completion and will furnish two stock judging pavilions, one large class room for agricultural work, a seed judging laboratory, and a large seed room for the storage of grains to be used for instructional and experimental work.

The Woman's Building has been practically completed for the use of the Department of Home Economics, furnishing dormitory facilities for sixty girls and class room and laboratory facilities for the School of Home Economics.

A machine shed has been built to house the farm tools, and other minor improvements have been made, such as bringing power from the University campus to use at the University farm. A greenhouse and potting rooms have been erected by the State Botanist and State Entomologist on the Station farm, out of special appropriations to investigate plant diseases and insect pests, under the State Insect Pest and Plant Disease Bureau established by the last Legislature. The Department of Entomology in the Experiment Station has been furnished quarters at the University farm. A milking machine has been purchased and put in operation to determine its utility for the practical dairyman.

At the Substation, since April, 1907, the following improvements have been made at approximately the cost named: Seed house and soil laboratory, $2,200; Herdsman's cottage, $1,300; cattle barn with elevator and grinder, $2,800; machine shed for farm tools, $500; heating, plumbing and gas at Superintendent's house and soil laboratory, $900; water system at central plant, $400; water system at west plant, $425; 20-horse gasoline engine and freight, $800; 4-horse gasoline engine and freight, $260; Huber threshing machine, $735; fencing, posts and labor for same, $1,000; approximate total cost, $11,320.

FARMERS' INSTITUTES.

Several members of the Experiment Station staff have assisted in Farmers' Institute work during the year. One hundred and thirty-six Institutes were held during the year closing June 30, 1907, and one hundred and seventy-five Institutes are scheduled for the current year. Ten thousand dollars per annum was appropriated by the last Legislature for the biennium beginning April 1, 1907.

Various agricultural societies meet at the University each year, under the name of Organized Agriculture, the following societies participating: The Association of Agricultural Students, the State Veterinary Medical Association, the Poland-China Breeders' Association, the Duroc-Jersey Breeders' Association, the State Board of Agriculture, the Dairymen's Association, State Horticultural Society, State Poultry Association, State Bee-Keepers' Association, State Swine Breeders' Association, Women's Department of Organized Agriculture, Park and Forestry Association, Improved Live Stock Breeders' Association, Boys' and Girls' Agricultural Associations, Corn Improvers' Association, Red Polled Breeders' Association, Farmers' Institute Convention, Aberdeen-Angus Breeders' Association, Shorthorn Breeders' Association.

PUBLICATIONS.

Bulletins giving the result of investigation in the Experiment Station are published in editions of from 20,000 to 25,000 each and are distributed free of charge to any resident of the state making application. There is at the present time a regular mailing list within the state of about 13,600 names. These are continually being added to, and it is desired that all farmers who are interested in the publications of this Station should ask to be placed upon this regular mailing list. The publications of the Station since those named in the last Annual Report are as follows:

Twentieth Annual Report. Presented to the Governor February 1, 1907. 5,000 copies.

Bulletin No. 95 (Substation Bulletin No. 1) (Vol. XIX, Art. II). Crop Production in Western Nebraska. Report of Experimental Substation, North Platte, Nebr. By W. P. Snyder, Superintendent, and E. A. Burnett, Director. Distributed March 18. 1907. 25,000 copies.

Bulletin No. 96 (Vol. XIX, Art. III). Some Insects Injurious to Wheat During 1905-1906. By Lawrence Bruner and Myron H. Swenk. Distributed March 18, 1907. 20,000 copies.

Bulletin No. 97 (Vol. XIX, Art. IV). Potato Experiments. By R. A. Emerson. Distributed April 13, 1907. 20,000 copies.

Bulletin No. 98 (Vol. XIX, Art. V). Spraying Demonstrations in Nebraska Apple Orchards. By R. A. Emerson. Distributed April 16, 1907. 20,000 copies.

Bulletin No. 99 (Substation Bulletin No. 2) (Vol. XIX, Art. VI). Growing Hogs in Western Nebraska. Report of Experimental Substation, North Platte, Nebr. By W. P. Snyder, Superintendent, and E. A. Burnett, Director. Distributed June, 1907. 30,000 copies.

Bulletin No. 100 (Vol. XX, Art. I). Economical Rations in Beef Production. By H. R. Smith. Distributed September 11, 1907. 25,000 copies.

Bulletin No. 101 (Vol. XX, Art. II). Part I, Dairy Herd Record for Ten Years; Part II, Cost of Butter Fat Production. By A. L. Haecker. Distributed November 18, 1907. 20,000 copies.

Bulletin No. 102 (Vol. XX, Art. III). The Effect of Bleaching upon the Quality of Wheat Flour. By F. J. Alway. Distributed October 23, 1907. 5,000 copies.

Bulletin No. 103 (Vol. XX, Art. IV). The Bud-Rot of Carnations, by F. D. Heald; A Mite Accompanying the Bud-Rot of Carnations, by Robert H. Wolcott. Submitted for publication October 15, 1907. Distributed January 10, 1908. 5,000 copies.

Bulletin No. 104 (Vol. XX, Art. V). Part I, Cultivation of Small Grains; Part II, The Use of the Fanning Mill for Selecting Seed Wheat and Seed Oats. By E. G. Montgomery. 5,000 copies.

Bulletin No. 105 (Substation Bulletin No. 3) (Vol. XX, Art. VI). Growing Cattle in Western Nebraska. Report of Experimental Substation, North Platte, Nebr. By W. P. Snyder, Superintendent, and E. A. Burnett, Director. 25,000 copies.

Press Bulletin No. 24. The Bleaching of Wheat Flour. By F. J. Alway. Distributed February 20, 1907. 3,000 copies.

Press Bulletin No. 25. The Seed of Cheat, Meadow Fescue and ter County, Nebraska, During the Winter of 1906-1907. By F. J. Alway and A. T. Peters. Distributed January 23, 1908. 20,000 copies.

One hundred and ninety-eight thousand bulletins and annual reports were printed for distribution by the Experiment Station during the year ending December 31, 1907. These publications represented 6,092,000 printed pages.

STATION MAIL.

Mail was received and sent out from the Experiment Station office during the year 1907 as follows:

Received—	Sent—
First Class.	First Class.
23,160 letters.	25,285 letters.
4,806 postals.	14,868 postals.
Second Class.	Second Class.
3,466 lbs.	703 lbs.
Third Class.	Third Class.
1,461 lbs.	1,010 pounds.
Fourth Class.	Fourth Class.
174 lbs.	112 lbs.
	Free List—
	16,370 lbs. regular bulletins.
	1,365 lbs. press bulletins.

ACKNOWLEDGMENTS.

The agricultural press, especially those papers located within the state, have shown their appreciation of the work of the Experiment Station by giving liberal space to the experimental work reported and in every way facilitating the extension of useful agricultural knowledge.

We are indebted to the Thirtieth Session of the Nebraska Legislature for its appreciation of the work of the Experiment Station, as expressed by increased appropriations for the experimental work at the North Platte Station and for the further equipment and maintenance of all the agricultural work in the University.

THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA

FINANCIAL STATEMENT

RECEIPTS

Received by the state treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1907, under the act of Congress approved March 2, 1887 (Hatch fund)	$15,000 00	

EXPENDITURES

Salaries		$9,431 04
Labor		1,316 54
Publications		2,232 14
Postage and stationery		374 69
Freight and express		52 08
Chemical supplies		71 38
Seeds, plants and sundry supplies		329 04
Feeding stuffs		404 15
Tools, implements and machinery		62 80
Furniture and fixtures		183 06
Scientific apparatus		310 28
Traveling expenses		217 80
Contingent expenses		15 00

RECEIPTS

Received by the state treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1907, under supplemental act of Congress approved March 16, 1906 (Adams fund)	$7,000 00	
EXPENDITURES		
Salaries		$5,307 82
Labor		102 63
Postage and stationery		78 90
Freight and express		154 49
Chemical supplies		238 73
Seeds, plants and sundry supplies		194 72
Fertilizers		134 84
Feeding stuffs		163 75
Tools, implements and machinery		35 80
Furniture and fixtures		45 00
Scientific apparatus		303 96
Traveling expenses		239 36
	$7,000 00	$7,000 00

SUPPLEMENTAL STATEMENT

RECEIPTS

Moneys received by the state treasurer from other sources than the United States, for the use and benefit of the Experiment Station and Substation, for the year ended July 31, 1907.

Balance July 31, 1906	$6,749 64	
Sales of stock, produce, etc	18,080 47	
EXPENDITURES		
Salaries		$2,415 21
Labor		2,551 40
Postage and stationery		440 90
Freight and express		449 03
Chemical supplies		17 26
Seeds, plants and sundry supplies		1,616 20
Feeding stuffs		5,574 01
Library		11 54
Tools, implements and machinery		906 41
Furniture and fixtures		57 50
Scientific apparatus		884 42
Live stock		1,746 44
Traveling expenses		517 69
Buildings and land		2,337 73
Balance, July 31, 1907		5,304 37
	$24,830 11	$24,830 11

STATE APPROPRIATIONS

FARMERS' INSTITUTES

Balance November 30, 1906, of state general fund appropriation	$5,368 16	
State general fund appropriation of 1907 for the two years ending March 31, 1909	20,000 00	
Expenditures to November 30, 1907, for superintendence, clerical services, labor, lecturers' service and expenses, printing, general supplies		$7,451 61
Appropriation balance November 30, 1907		17,916 55
	$25,368 16	$25,368 16

SUBSTATION (North Platte)

State general fund appropriation of 1907, for the two years ending March 31, 1909	$25,000 00	
Expenditures to November 30, 1907, for superintendence, labor, live stock, feed, seeds, tools, machinery, general supplies, and permanent improvements		$16,162 10
Appropriation balance November 30, 1907		8,837 90
	$25,000 00	$25,000 00

J. S. DALES,
Financial Secretary.

LINCOLN, NEBR.,
December 18. 1907.

SOME TOMATO FRUIT ROTS DURING 1907.

BY VENUS WORRELL POOL.

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SOME TOMATO FRUIT ROTS DURING 1907.*

BY VENUS WORRELL POOL.†

INTRODUCTION.

Various diseases of the tomato (*Lycopersicum esculentum*) have long been known and described. Altho many common fungi, no doubt, have the power of rotting the overripe fruit, the number is still limited which are able to grow upon the green or just ripening.

The fungi which are herein described were studied during the summer of 1907. No entirely unknown organisms were found, but several new characters of those which are more or less familiar have been observed which it might be well to add to the facts already known of these fruit rots.

The varieties of tomatoes which were used in the inoculations were the "Dwarf Champion," "Stone" and a special called "Wonder Magnus" which was one of the potato-leaved varieties. The "Dwarf Champion" as a rule did not yield so readily as the others to the rotting organisms, even under laboratory conditions.

"BLACK ROT."

Alternaria fasciculata (C&E) Jones & Grout.

OBSERVED SYMPTOMS.

The ripe fruit examined had the diseased spot at the blossom end, slightly wrinkled and dark brown to almost black in color. The collapsed flattened area extended almost across the upper surface of the fruit. (Pl. I, fig. 4.) The underlying tissues of the older portions were extremely hardened in places, the intervening cavities being filled with fluffy fungus mycelium. A microscopical examination of the tissues revealed a dense formation of very dark, almost black hyphae in the older areas, while brownish colored filaments extended into the surrounding healthy tissues.

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* Submitted as a thesis for the degree of Master of Arts, University of Nebraska, 1908.

† Assistant in Plant Pathology.

Sections made of such tissue taken from artificially infected spots revealed something of the nature of the pathological condition. The tough, hard portions are made up of a compact aggregate of swollen, almost spherical cells; some of these are rather thick walled, densely pigmented and stand out in bold relief in the midst of the surrounding brown colored ones. (Pl. II, fig. 7.) The transition from this portion to the neighboring cavity (Pl. II, fig. 6), filled with a lightly woven mass of ordinary filaments, is very abrupt. No cellular structure is distinguishable, such structure being found only in the lately rotted areas.

ISOLATIONS AND INOCULATIONS.

Glucose agar planted plate cultures made from portions of the diseased tissue, resulted in a perfectly pure growth of an *Alternaria*. Inoculations were made from the cultures obtained in this way. Five days after infection had taken place in the ripe fruit, the rotted area measured one-half inch in diameter. In ten days to two weeks the ripe tomatoes were rotted and collapsed thru one-third their entire extent. The tissue was hard, leathery and blackened, resembling the original in every particular.

No change or growth took place in the green fruit.

Glucose agar planted plate cultures made from the tissue in color than the fertile. Conidiophores when mature, dark as the conidia and measure 30-44 microns by 4-5 microns. Conidia, dark brown, 35-66 microns by 16-20 microns, with three to six transverse and one to two longitudinal septa. Apical cell hyaline to light brown, often producing a short side branch which forms one to several conidia. These side chains are characteristic, occurring frequently. Mature conidia and hyphae prominently echinulate. (Pl. II, fig. 8.)

HISTORICAL ETIOLOGY.

Since "Black Rot" has been known and described, various names have been given to the causal organism. Notwithstanding this, the same fungus probably has been observed when this particular form of the disease has been noted.

Macrosporium tomato Cke. was first[1] reported as occurring upon ripe tomatoes in South Carolina in 1883. Later Galloway[2] described the disease "Black Rot," giving as the causal organisms *M. tomato* Cke. and *Fusarium solani* Mart. He states that "infection of both green and ripe fruit was readily effected by inserting the *Macrosporium* spores under the skin." *M. solani* was also given by other writers as the causal organism.

Jones & Grout[3] in 1896-7 "found that the fungus which causes the black patches on the rotting fruit was an *Alternaria,* and further proved that this fungus did not cause the rot, for green tomatoes inoculated with spores from a pure culture from the tomato remained in a moist chamber until they ripened without showing signs of the rot, and cultures made from tomatoes just beginning to rot would not yield the *Alternaria.*"

McAlpine[4] reported a tomato rot from N. S. Wales caused by *Alternaria rugosa.* The description agrees with that of the one under consideration with the exception of the color of the hyphae, which were neutral to grayish.

chartarum Pk., *M. fasciculatum* C&E, *M. tomato* Cke. and *M. maydis* C&E. The description and illustration given agree with that of the fungus under consideration. The two doubtless are identical.

Alternaria fasciculata (C&E) Jones & Grout does not cause a rot of the green fruit but does produce a pronounced decay of the ripe, duplicating in an artificial infection the original black, hard, leathery condition of the tissues.

CULTURAL CHARACTERS.

On 3 per cent glucose agar (+10): At first the mycelial growth is light colored, almost white, fluffy; later it becomes dark gray with medium much darkened. Not an abundant production of conidia.

On tomato agar (3 gr. agar to 100 cc. tomato juice), or stewed tomato or corn-meal: Very similar to the preceding.

On steamed carrot or banana: Growth heavy, fluffy, grayish green. Mycelium blackish green where the surface of glass is touched. Spore production, but not abundant.

On steamed potato: Growth light gray with slight darkening in places. Potato darkened beneath growth. Mycelium not fluffy but clinging mat-like to the surface. No spore production.

RHIZOCTONIA ON THE TOMATO.

HISTORY.

In the Florida station report[5] for 1905 an account is given of the occurrence of the potato *Rhizoctonia* upon the tomato fruit.

Corticium of the potato." This is the only description found of a *Rhizoctonia* upon the tomato fruit.

SYMPTOMS.

The specimen examined showed no rupture in the external skin visible to the naked eye. The diseased area was plainly distinguishable by the chocolate-colored, slightly wrinkled epidermis. An examination of the underlying tissues revealed the same general color and numerous somewhat darkened filaments penetrating the cells in all directions. No conidia or fruiting bodies of any kind have yet been observed. It has not yet been determined whether this *Rhizoctonia* is *Corticium vagum* B&C, the one that occurs upon the potato.

ISOLATIONS AND INOCULATIONS.

A pure culture of the fungus was obtained by the planted plate method. Green tomatoes only were used in the first series of inoculations. Three days after infection the discolored areas around the points of inoculation measured one-half inch in diameter. In three more days the older external hyphae had formed a close matted mycelial growth, while the new filaments had reached almost around the entire fruit surface. In ten days to two weeks the tomatoes were completely rotted.

In the second series green and ripe fruits were used. Seven days from the time of infection, the green specimens were rotted thruout. The tissues remained firm but were changed to a chocolate brown and emitted a toadstool-like odor, which is characteristic of new growths of the fungus. The ripe tomatoes presented much the same appearance with the exception of a fruit thru the unbroken epidermis has not as yet been demonstrated.

VEGETATIVE CHARACTERS OF THE FUNGUS.

The fungus agrees with the descriptions of *Rhizoctonia* in general,[6, 7] especially in the following details:

"The young branches are inclined to the direction of the growth of the parent stem, and the former are somewhat narrowed or constricted where united with the latter.

"Young hyphae are strongly vacuolate but later they become uniformly granular and more deeply colored. Branching also seems to have occurred more nearly at right angles to the main hyphae." (Pl. IV, fig. 11.)

The numerous sclerotia produced (Pl. III, fig. 10) are made up of closely septate hyphae. The cells which compose the hyphae may be very irregular in shape and dark colored or the cells may be of a lighter brown and vary little in form, making up almost straight hyphae (Pl. IV, fig. 12). Such aggregates of hyphae are very easily broken up, each cell having the power of forming a new growth.

CULTURAL CHARACTERS.

Tomato agar: At first, white, matted growth clinging to medium; later the growth darkens next to the medium and a few sclerotia are formed.

Stewed tomato: Similar to preceding.

Corn-meal: In two days mycelial growth thinly spreading over corn-meal cake, with a fluffy white ring at its edge. Later, dark brown sclerotia with a dented central portion are formed. (Pl. III, fig. 10.)

Compost: A slight growth which soon disappeared.

Steamed potato: In twenty-four hours fungus colony 15 millimeters in diameter, thin mycelium, potato cylinder browned over a great portion of its exposed surface. Later typical sclerotia are formed.

Glucose agar: At first mycelium thin, spreading, white, later producing sclerotia similar to preceding.

Steamed carrot: Mycelium identical with that upon potato. The manner of growth is more *Rhizoctonia*-like, the filaments spreading parallel to each other, while along their lengths numerous sclerotia are formed.

"RIPE ROT" OR ANTHRACNOSE OF THE TOMATO.

Colletotrichum lycopersici Chester.

SYMPTOMS.

The diseased spots may vary from small, sunken, smooth areas, sometimes darker in color than the surrounding healthy tissue, again yellow and dotted with the small fruit masses or acervuli of the fungus, to large roughened areas, brown to almost black, covering an entire side of the fruit. A great many of the older spots have a characteristic which is very noticeable, that is, the zonation rings. These are plainly shown in Plate I, figure 1. In such a concentrically arranged spot the acervuli will be massed together in circles, while a portion of firmer tissue with no external evidence of disease intervenes. This zonation may be noticed in the first photograph taken of this anthracnose by Chester.[8] In Plate I, figure 3, the diseased area either presents a homogeneous surface with the acervuli arranged promiscuously, or only a slight zonation is noted. In the several isolations and inoculations made, it was observed that the tomatoes kept in the light developed this zonation while the cultures in the dark formed an even, continuous growth. No field observations were made, however, as to the position of the various fruits with reference to sunlight and shade, altho this is probably the cause of the appearance or nonappearance of the fruiting rings.

The deeper tissues of the anthracnose spots are always filled with an immense number of spores. These commence to be formed as soon as the fungus has grown for a day or two. The acervuli are only found after the growth has continued for some time.

HISTORICAL ETIOLOGY.

Gloeosporium phomoides was first described by Saccardo[20] as producing a rot of ripe tomatoes.

In 1884 Arthur[21] reported the same fungus as "rupturing the epidermis and producing great numbers of spores on the ends of the protruding mycelium."

In 1891 Chester[8] found that a fungus which caused an anthracnose of the tomato was a *Colletotrichum,* and believing it to be a new species named it *C. lycopersici.* In 1892 he says[9] "the fungus which in 1891 was clearly a *Colletotrichum* from the abundant development of setae was in 1892 without setae and to all appearances a *Gloeosporium.*" In 1893[10] "inoculation of tomatoes with what was apparently *G. Phomoides* resulted in at first a pinkish stroma without setae but which afterwards turned darker and developed perfect setae. In artificial cultures of the fungus it seems to bear a relation to age."

Cobb[11] in 1895 reported a "pimply rot of the tomato." While he did not name the causal organism, the photograph and description of the disease agree with that of *C. lycopersici* Ches. The spore measurements are much smaller, 2-3 microns by 5-7 microns.

In 1898 Miss Stoneman[24] gives a brief description of both anthracnoses. She states that "the colonies of the two anthracnoses are quite different. The *Gloeosporium* acervuli lie well imbedded beneath the epidermis, the short continuous basidia not projecting beyond the host. In the *Colletotrichum* colonies the acervuli are erumpent and the setae are sometimes lacking; black spherical perithecial-like bodies are formed which produce

Confusion seems to have existed as to the proper naming of the anthracnoses. However, conclusions drawn from these previous investigations point to the occurrence of two anthracnoses upon the tomato, one produced by *Gloeosporium Phomoides* Sacc. and one by *Colletotrichum lycopersici* Ches. The former is characterized by an imbedded acervulus without setae, while the latter forms an erumpent acervulus with or without setae.

FUNGUS CHARACTERS.

The conidia measure 10-18 microns long by 2.5-5.5 microns wide, which is somewhat less than that given in the original description.[8] The size of setae and acervuli agree. In a 3 per cent glucose agar (+10) culture at 26° C., the fungus spores germinate in a few hours. In 18 to 24 hours an abundance of primary conidia are produced. They are formed by the pinching off of the hyphal end of the simple conidiophores, which process requires only one-half to three-fourths of an hour (Pl. IV, fig. 13). The spores do not remain in clusters around the hyphal end but soon disappear into the surrounding medium. Their formation was successfully determined by the usual hanging drop method. This manner of spore production is evidently followed by the fungus in producing the quantities of conidia found in the deeper tissues of the anthracnose spot (Pl. V, fig. 15).

Upon artificial culture media, young colonies are white to pink in color. When examined microscopically an abundance of hyphae and conidia are found. Later the colony commences to turn dark at and around the central or older portion. The cells enlarge to two or three times their usual diameter, become more or less spherical in shape (Pl. IV, fig. 14), form many vacuoles, and take on a dark brown color. If an examination is now made, few if any conidia are found in this darkened portion, altho they occur abundantly near the edge of the colony where the new growth continues. As these darkened masses are developed, the conidia formation ceases. The spores which have been produced germinate and grow into a new mycelium. The latter, due to lack of nutrition, does not produce spores a second time. The blackened areas gradually heap up until they are more or less spherical and somewhat confluent. They are sterile and may or may not produce setae.

At times, especially in freshly isolated cultures, small pinkish heaps precede the formation of the black aggregations. These seem to be the typical acervulus with setae and spores.

Under natural conditions, an examination of the tissues of an anthracnose spot which has not yet produced acervuli, shows an abundant production of primary spores which are formed in the same manner as that of the conidia in cultures. As the spot becomes older, pink acervuli may be formed. These invariably consist of parallel arranged fungus tissue whose hyphal ends bear the setae and the secondary spores (Pl. V, fig. 15). The latter are identical in size and appearance with the primary conidia. As these acervuli become older, the central portion of the fungus tissue turns black (Pl. VI, fig. 17). This process gradually continues until the entire acervulus is one blackened heap (Pl. VI, fig. 16). The setae apparently break or fall off, as little or no evidence was found of their previous existence. The conidia also disappear, falling upon the surrounding tissue or scattering elsewhere.

At times these blackened heaps occur upon the anthracnose spot from the time the epidermis is ruptured by the fungus. In such a case few typical acervuli are developed. The spherical dark aggregations are identical with those produced in artificial cultures. They germinate readily, producing a vigorous growth when placed under favorable conditions.

APPRESSORIA.

The appressoria (Pl. VII, fig. 18) as found in this species are oval bodies, smooth in outline or with knob-like projections, dark brown, and contain a few large oil drops. They are invariably the first objects to come into focus when a hanging drop preparation is examined. Certain hyphae seem to grow up towards the cover glass and when it is reached, thru mechanical stimulus or otherwise, these attachment organs are formed.

Conidia placed in a hanging drop of water and incubated at 26° C. produced appressoria within two days. No spores were formed until the third day, when a very few were found. The number of appressoria increased slightly up to the fifth day, after which time there was no appreciable change.

Following exactly the same method and conditions, conidia were germinated in a 3 per cent glucose agar (+10) hanging drop culture. Within twenty-four hours an immense number of spores were produced but no appressoria were distinguishable. By the third day, however, appressoria were developed in greater abundance than in the preceding culture. In both cases the appressoria were formed without reference to the surrounding medium.

While more appressoria were formed in the latter culture than in the former, a greater mycelial growth was made, thus giving a chance and need for greater attachment. Since adverse conditions did not seem to cause a greater production of these bodies, it does not appear probable, in this species at least, that the special bodies formed are for the purpose of tiding the fungus over an unfavorable period. Hasselbring[16] found for *Gloeosporium fructigenum* and Halsted[17] for other species, that "a rich nutritive medium produces only a meager supply of special cells while pure water yields few spores and many dark bodies." There is the tendency that Hasselbring mentions, "the hypha which grows in a nutrient medium commences to form an appressorium but before this is formed the hypha grows out again and attempts to repeat the process," in this way forming an irregular chain of swollen hyphal cells. (Pl. VII, fig. 19.)

ISOLATIONS AND INOCULATIONS.

The fungus was repeatedly isolated in pure cultures by the planted plate method. Exactly the same cultures were obtained from small, smooth, sunken spots, as seen in Plate I, figure 2, as from well developed spots (fig. 3) which had produced an abundance of acervuli. These cultures were used indiscriminately in the inoculations.

Four days after infection the diseased area measured one-fourth inch in diameter on the average. This was true of both green and ripe tomatoes. No acervuli were formed at this time but an internal examination gave evidence of an abundant formation of the primary spores.

The spots increased in extent slowly even under ideal conditions. In two weeks' time, or longer, the size of the diseased area had increased but little; the acervuli had made their appearance, however, as small pinkish heaps. These gradually increased in density and color, eventually becoming black masses of cells, setae and spores.

CULTURAL CHARACTERS.

Tomato agar: Cultures one week old. Growth heavy, compact, membrane-like, pink with an abundant production of spores. Later growth roughened with the black masses of acervuli scattered over the surface.

Stewed tomato: At first mycelial growth clinging to surface of medium, brownish pink. Later, surface blackened with masses of acervuli.

Three per cent glucose agar (+10): The fungus presents the same appearance as upon tomato agar.

Corn-meal: At first mycelium grayish green, not membranous but rising slightly above the medium; colony edge pink, shading into white. Later when mycelial growth is carefully scraped away, the characteristic small heaps or acervuli may be seen next the medium.

Potato: Mycelium pink, edged with white and covering medium closely. Acervuli next medium hidden by the filamentous growth.

Carrot: Growth resembling that upon the potato.

Banana: Mycelium at first fluffy, later, in month-old culture, medium shrunken, black, covered with a roughened heap of acervuli.

FUSARIUM SP.

SYMPTOMS.

The first tomatoes which ripened in one garden under observation were apparently sound and healthy, the external surface was smooth and plump with no evidence of internal softened areas. However, upon cutting into the fruits, a fourth to one-half of the inner tissues was found to be darkened and shriveled. The dry, shrunken, greenish black tissue was usually located near the center of the fruit, in the cavities around the seeds. The external thick tissues were usually healthy and firm, giving the tomato a normal appearance externally (Pl. I, fig. 5). The tissue was repeatedly examined but no evidence of the presence of fungus filaments was found. The examinations were not satisfactory, however, on account of the dry, collapsed condition. Bacteria were frequently observed.

ISOLATIONS AND INOCULATIONS.

Pieces of diseased tissue were at various times placed in glucose agar plate cultures, but no constant results were obtained. The same was true of the various poured plate series.

Several times similar bacterial colonies developed around the points of inoculation in the planted plates and in the series of poured plates, in such abundance that it was thought these might be the causal organisms. Pure cultures were obtained and inoculations made into both green and ripe tomatoes, but no infection resulted.

In one series of poured plates, numerous fungus colonies of similar appearance developed. From a pure culture of this fungus, inoculations were made into the green and ripe fruits. After three or four days, the fungus hyphae had penetrated the surrounding tissues to the extent of one fourth to one half inch. The growth occurred the same upon the green and ripe specimens. The hyphae also grew externally in tufts, which were made up of numerous fascicles, which in turn produced a great abundance of conidia.

Isolations from the artificially rotted fruits yielded the original fungus.

Evidently this fungus could produce a rot of the tissues, but the characters of the disease did not resemble the original in any way. The diseased tissues of the artificial rot were only slightly darkened and rather watery in appearance, strongly contrasting with instead of agreeing with the dry, dark green to black tissue of the original. For this reason the fungus is not given a specific name. Altho the connection between the fungus and the specific disease is not known, it is a genuine fruit rot, and as such is described.

DESCRIPTION OF THE FUNGUS.

The conidia germinate in a few hours at 25° C. in a 3 per cent glucose agar (+10) culture, and in twenty-four hours the short germinating tubes have produced an abundance of spores. Two kinds of conidia are formed, microconidia and macroconidia. The microconidia are borne upon very short conidiophores, being hardly more than a side growth of the cell (Pl. IX, figs. 28-32). The conidia are formed by the simple process of constriction. They remain clustered around the hyphal end until six to eight spores are massed together, when the particular hypha ceases to form more. Conidia are nonseptate, oval, and measure 3-4 microns wide by 4-14 microns long.

The macroconidia are produced in a similar fashion at the ends of long condiophores (Pl. IX, figs. 23-27), the latter perhaps bearing microconidia upon short side branches. From the number of conidia whose growth was continuously observed, only two became uniseptate and then only just before germination took place. When plain agar was used in the place of glucose agar, the conidia were much smaller and commonly one to two septate, resembling somewhat the typical *Fusarium* spore.

The macroconidia commonly measure 3-5 microns by 16-22 microns.

HISTORICAL.

Beach[18] mentions a blackening of the tomato fruit tissues which may be seen externally as well as internally. The disease "occurred most frequently on the early fruits of rapidly growing plants but continued to appear thruout the season. The remarkable feature of this rot is the total absence of fungus hyphae from the tissues of the fruits in the early stages of the disease." This is the only report found in which reference is made to this peculiar condition of the tomato fruit.

CULTURAL CHARACTERS.

Tomato agar: Growth rather fluffy, white, with a shade of lavender.

Stewed tomato: Growth fluffy, white with a pinkish tinge.

Corn-meal: Growth fluffy, white with a tinge of lavender, medium changed to a purple which is very characteristic.

Glucose agar: At first culture is pure white, later becoming purple at the edge of the medium. The lavender pigment does not extend into the hyphae but remains in the medium.

Potato: Growth clings to surface, rising but slightly above it, pure white.

Carrot, banana: Mycelium compact, fluffy, soon filling tube, white.

FUSARIUM SOLANI MART.

SYMPTOMS.

The outside of the fruit presents an unbroken epidermis. The diseased area is recognized by a wrinkled area, somewhat darker red in color than the surrounding epidermis. The underlying tissues are of a lighter color, shrunken and filled with fungus filaments. The central portion of the diseased area is compact, dry and can be lifted out as a "core." The tissue around this shows dark red, softened areas, which upon examination reveal a great hyphal development.

ISOLATIONS AND INOCULATIONS.

From the pure cultures obtained by the usual method, inoculations were made into the ripe and green tomatoes. In three to five days the rotted area on the ripe fruits measured from one-half to one inch in surface diameter, and extended one-third thru the entire fruit. The hyphae grew externally in tufts, which produced an immense number of sickle-shaped spores.

The fungus seems to have very little effect upon the green fruits, penetrating the tissues but slightly. However, the mycelium is able to grow sufficiently to produce a tuft of external hyphae, which attain a slight growth and then become dormant.

DESCRIPTION OF THE FUNGUS.

The conidia germinate in a few hours at 26° C. on ordinary culture media. In twenty-four hours a dense mycelium is formed but no spores are produced until the fungus has grown for two or three days. The conidia are borne upon upright conidiophores which may be simple or branched. The branching is very characteristic, the conidiophores often presenting a tree-like effect with their side branches, and the not uncommon three terminal branches.

The conidia are sickle-shaped, three to five septate and measure 24-44 microns by 2.5-5 microns. No microconidia have been observed. (Pl. X.)

HISTORICAL ETIOLOGY.

The fungus under consideration doubtless is the same as Galloway[2] has described. The illustrations of the two fungi point to the same species. Galloway also found that *F. solani* would not penetrate the green fruit altho it so readily produced the decay of the ripe.

This last year a bulletin[19] has been issued which describes a fungus (*Fusarium solani* Mart.) which was able to produce a rot of even the small green fruits, blackening the tissues in a peculiar way. This characteristic and the manner of spore production point to another species rather than to the one under consideration.

CULTURAL CHARACTERS.

The fungus was grown upon tomato agar, stewed tomato, corn-meal, glucose agar, potato, carrot and banana, with similar results. The mycelial growth is fluffy, cottony, varying from pure white to white with a pinkish cast. After a few days ar abundant production of conidia upon all media.

PREVALENCE OF THE ROTS.

The Experiment Station plat and two home gardens were under observation.

The anthracnose or "ripe rot" of the tomato was found upon almost all of the later tomatoes which ripened in the plat of the Experiment Station, rendering the fruits practically worthless. This rot did not occur in the two other gardens.

The peculiar blackened condition produced by *Fusarium* sp. was found in fully one half of the earliest fruits which ripened in one of the home gardens, as shown by the numbers of tomatoes which were cut open and found to be in this condition.

The other rots occurred in greater or less abundance during the main part of the season. The loss was not estimated as no check was available as to the amounts of fruit there would be if no disease occurred.

PREVENTIVE MEASURES.

The tomato rots, like the majority of all plant diseases, can not be held in check to any great degree after they are once established. Preventive measures applied in time, however, should keep the loss of fruits at a minimum.

The measures here recommended are gleaned from the reports

Tomatoes may grow and thrive upon the same land year after year, with the employment of proper sanitary measures. As compared, however, with tomatoes grown upon land under rotation, the fruit is inferior in quality and quantity, and is much more liable to rot.

Plants which have an upright position with smooth, thick-skinned fruits, as the "Dwarf Champion," are freer from disease than the trailing thin-skinned varieties, "Stone." The training of the vines was not found advisable.

It is advocated by others[23] that "any system of training which allows free access of air and sun to the fruits and holds plants above the ground, decreases the rot. However, branches must be pinched out, or the trellis becomes an interminable mass of foliage."

Sanitary measures should be employed at all times. The rotting, decayed fruit should be removed and burnt, and a thoro application of Bordeaux mixture should be given every two weeks during the growing season.

The Department of Agriculture[24] as far back as 1889 gives this convincing evidence of the benefit of efficient spraying.

Section	Treated with	Loss from rot
1	Bordeaux mixture	4 per cent
2	No treatment	64 per cent
3	Ammoniacal solution	20 per cent

Bordeaux mixture of the formula 6-4-50 or 5-4-50 should be used.

Acknowledgments are due Dr. F. D. Heald, Botanist of the

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EXPLANATION OF PLATES.

Plate I.

Fig. 1. Tomato fruit with large mature anthracnose spot showing definite zonation rings.

Fig. 2. Tomato fruit showing the very immature, smooth, anthracnose spots which have produced but slight indentations.

Fig. 3. Two tomato fruits showing large anthracnose spots with a homogeneous arrangement of the acervuli.

Fig. 4. Tomato fruit with portion blackened and collapsed by *Alternaria fasciculata.*

Fig. 5. Tomato fruit showing normal external appearance with collapsed internal darkened tissue caused by *Fusarium* sp.

Plate II.

Fig. 6. *Alternaria fasciculata* showing method of conidia formation.

Fig. 7. Section thru portion of tomato tissue hardened by the *Alternaria* rot and showing the intensely dark cells surrounded by brown colored closely massed ones.

Fig. 8. An adjoining cavity filled with a loose mass of fungus filaments.

Plate III.

Fig. 9. Glucose agar culture of *Alternaria fasciculata* isolated from an artificially infected fruit.

Fig. 10. Sclerotia formation of *Rhizoctonia* upon a corn-meal cake.

Plate IV.

Fig. 11. Immature *Rhizoctonia* hyphae showing the vacuolation and peculiar constriction at the origin of the branches.

Fig. 12. Sclerotia hyphae with short, brown colored cells.

Fig. 13. Time development of primary conidia of *Colletotrichum lycopersici.*

Fig. 14. An aggregation of enlarged, spherical, vacuolate, dark brown cells, the forerunner of the blackened masses found in artificial cultures and occasional natural infections of *C. lycopersici.*

Plate V.

Fig. 15. A section thru a typical acervulus of *C. lycopersici* showing the fungus hyphae and primary conidia in the under-

Plate VI.

Fig. 16. Section thru a blackened spherical heap of *C. lycopersici*. The dark fungus cells have completely replaced the tissue of the acervulus.

Fig. 17. Section thru an acervulus which is just commencing to be replaced by the blackened fungus cells.

Plate VII.

Fig. 18. Appressoria of *C. lycopersici* formed in a 3 per cent glucose agar (+10) culture.

Fig. 19. Sometimes before an appressorium was completely formed the hypha grew out and attempted to repeat the process, forming an irregular chain of hyphal cells.

Plate VIII.

Fig. 20. A tomato fruit artificially infected with *Fusarium* sp.

Fig. 21. A tomato fruit artifically infected with *F. solani.*

Fig. 22. A tomato fruit artificially infected with *Rhizoctonia.*

Plate IX.

Figs. 23-27. Time development of macroconidia of *Fusarium* sp.

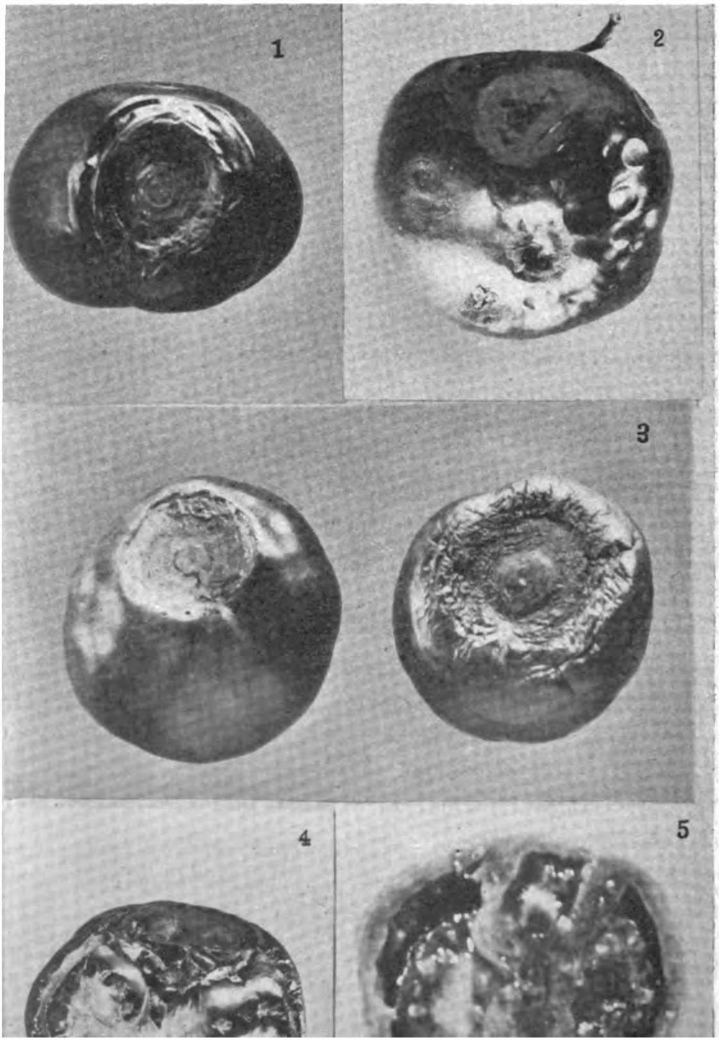
Figs. 28-32. Time development of microconidia of *Fusarium* sp.

Plate X.

Fig. 33. Conidial formation of *Fusarium solani.*

Agricultural Experiment Station of Nebraska.

PLATE I.



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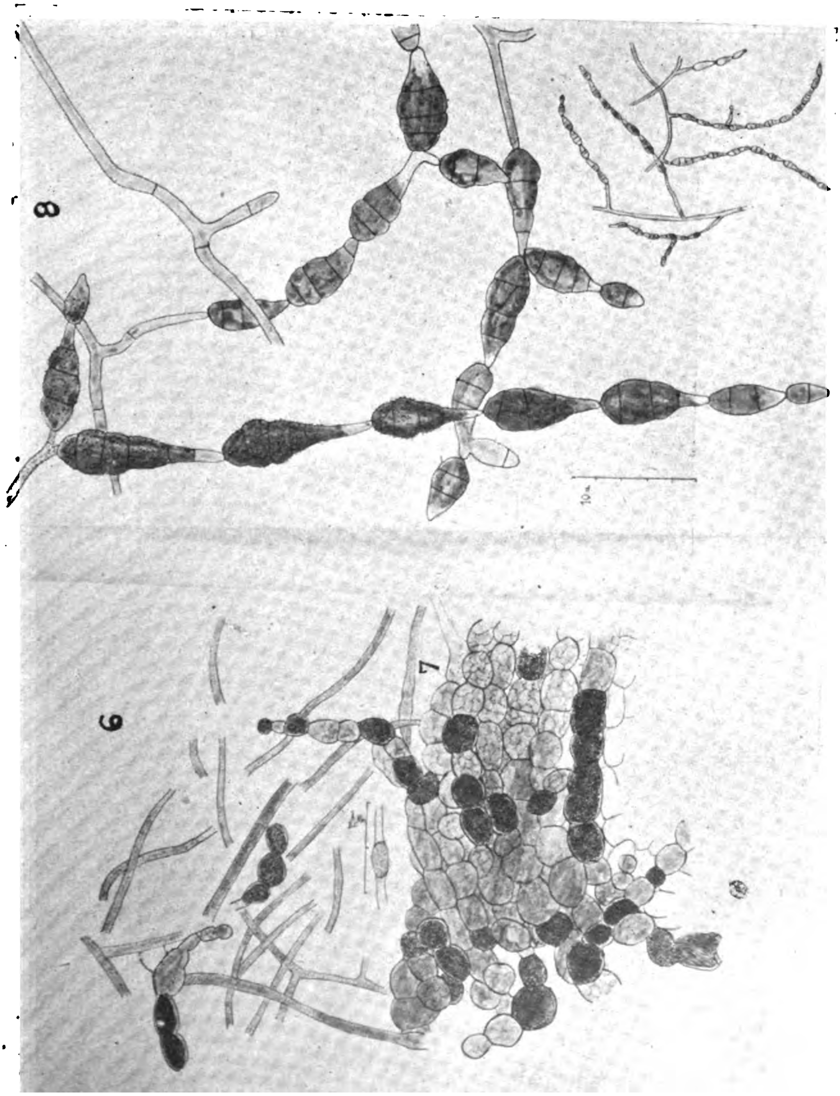

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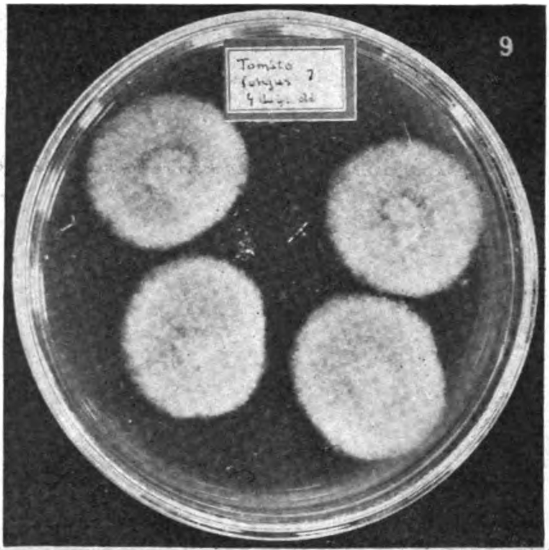

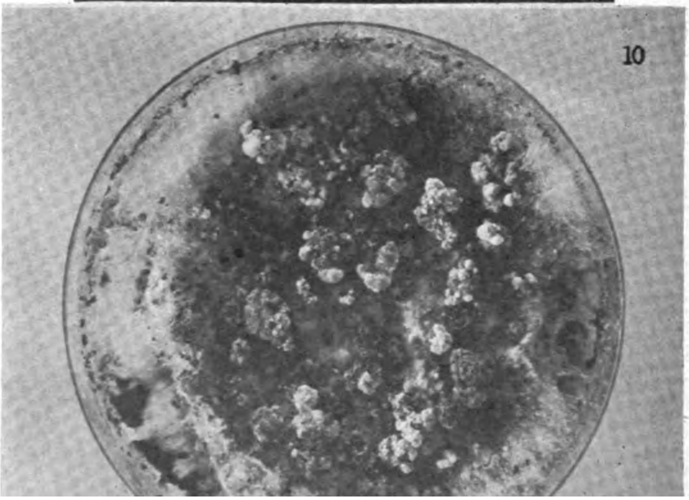

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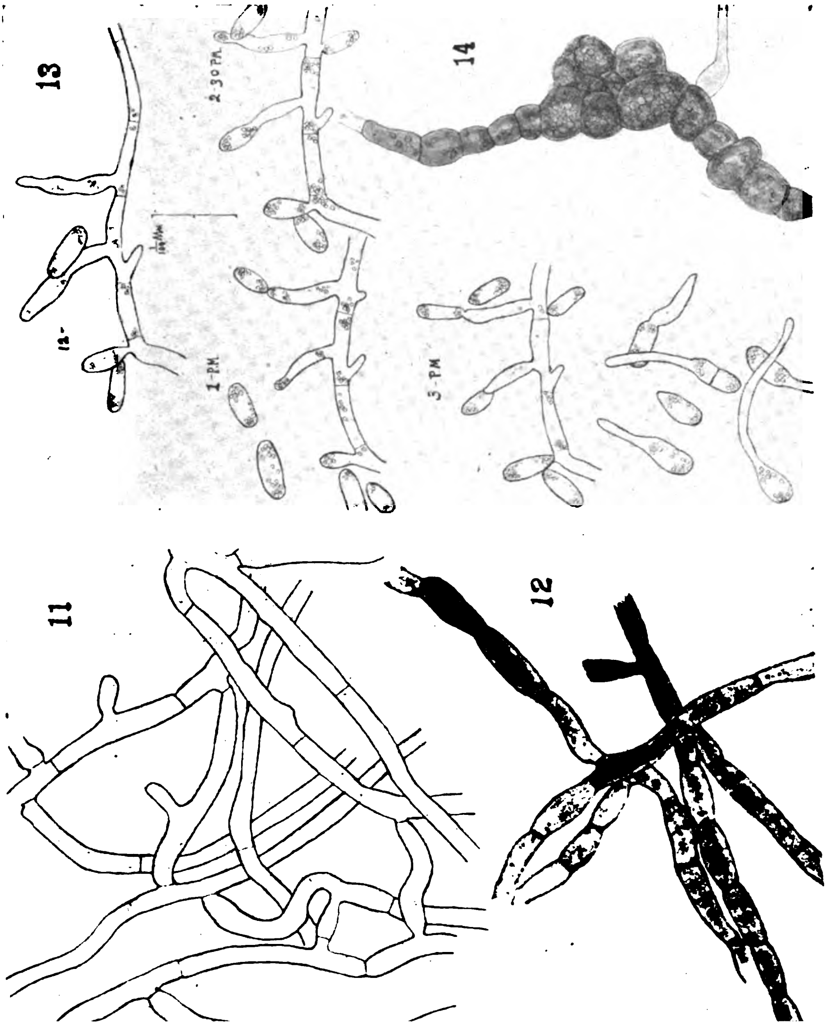

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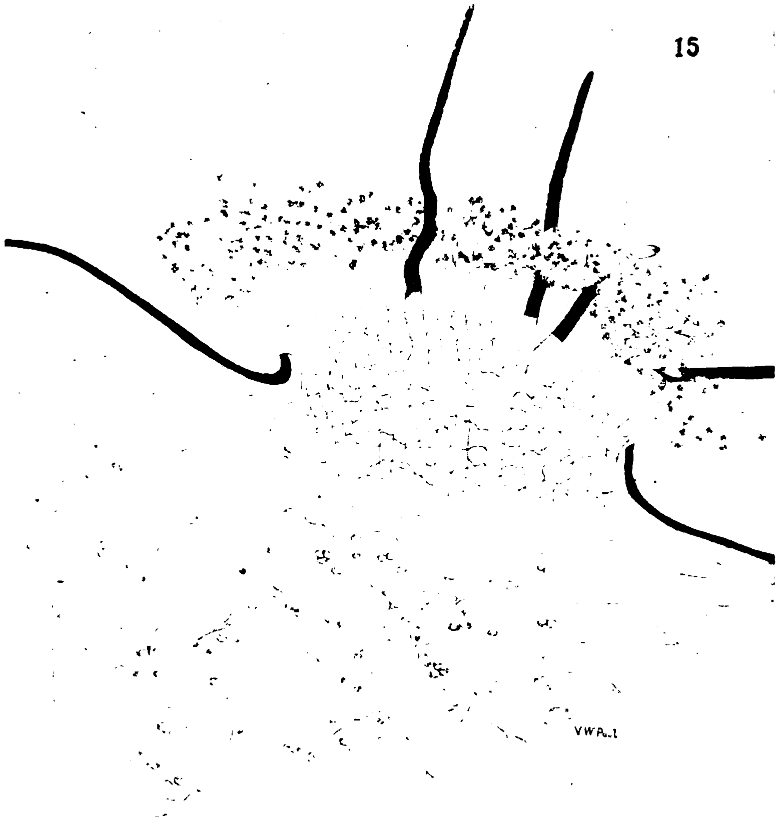

PLATE VI.

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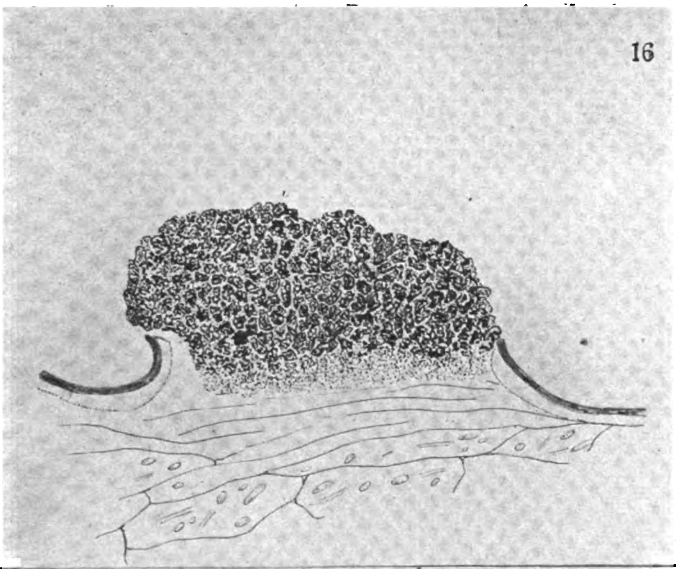

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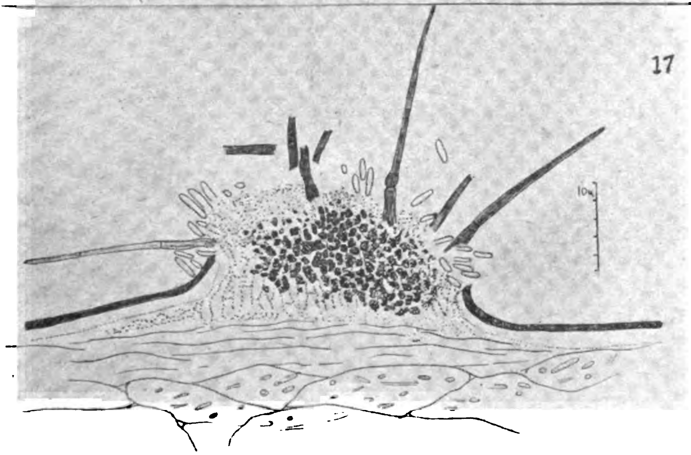

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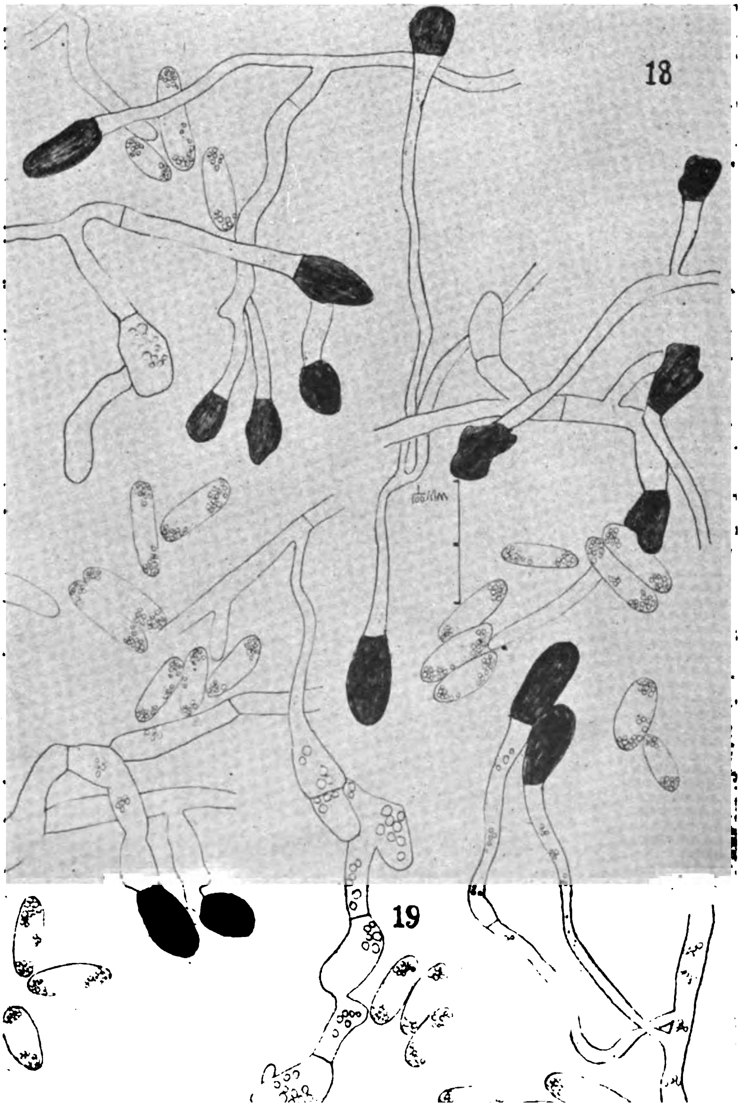

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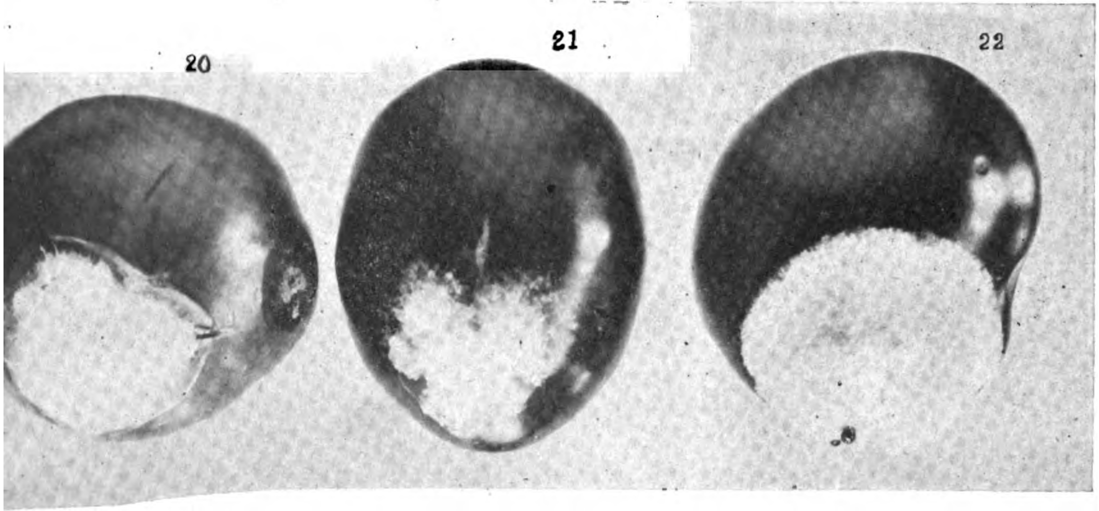

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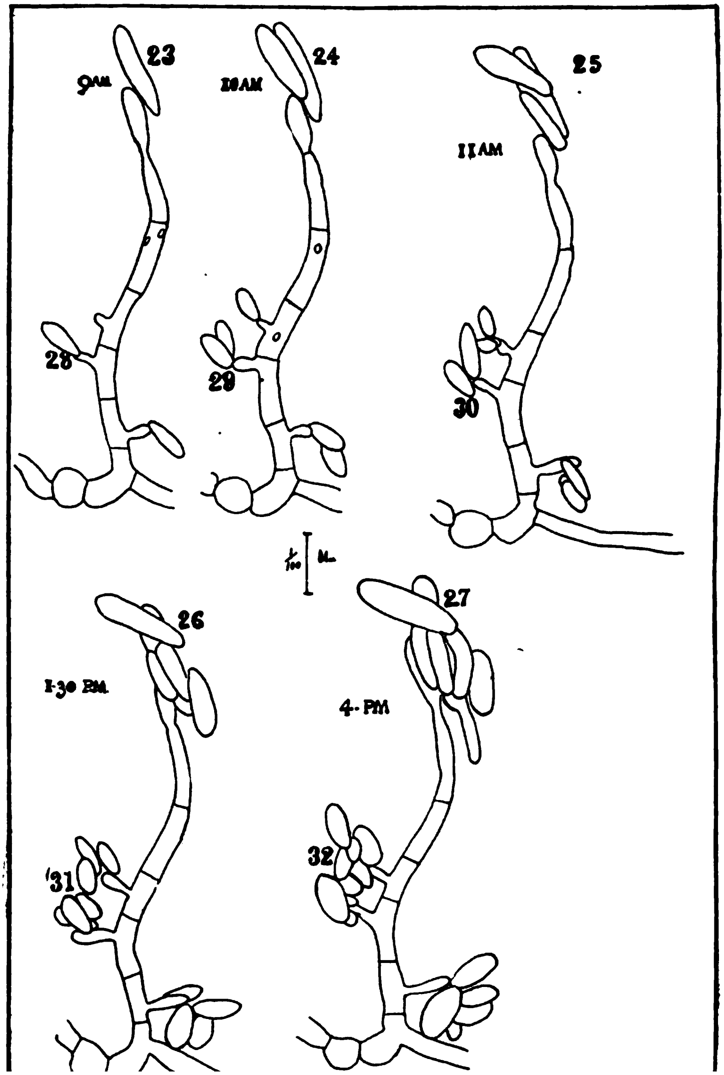

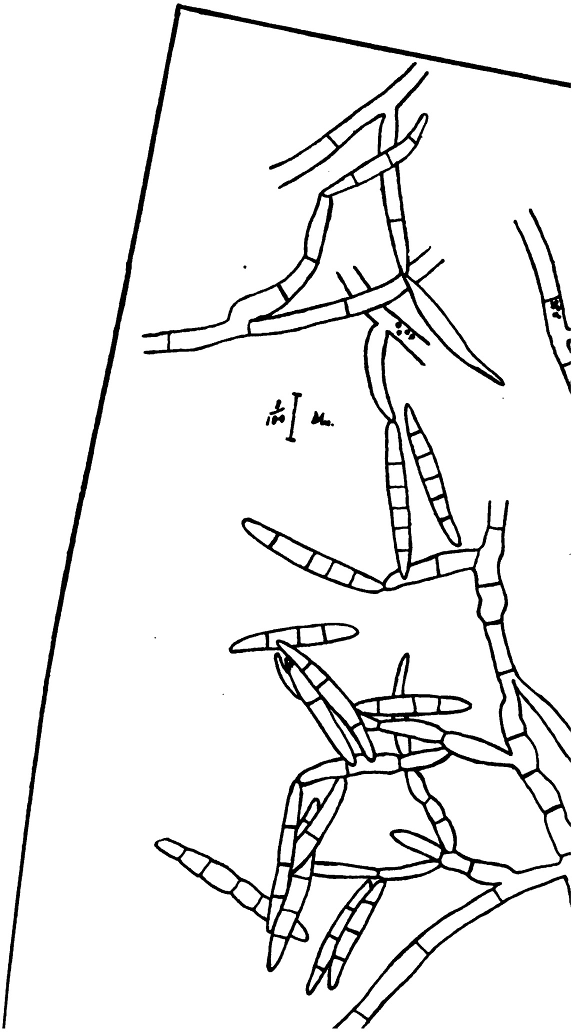
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A NEW FORM OF *SPHAEROPSIS* ON APPLES.

BY LEVA BELLE WALKER.*

Two forms of *Sphaeropsis* have been observed which are capable of producing a severe black rot of the apple. The macroscopic appearance of the rots is very much the same. The principal differences in the two forms are in the size of the spore, the size and thickness of the pycnidium, and the absence of the ostiole in the new form. The new form also seems to be a much more vigorous rot producer.

In this discussion the typical *Sphaeropsis malorum,* the new form and the differences and possible relations of the two forms are respectively considered.

SPHAEROPSIS MALORUM.

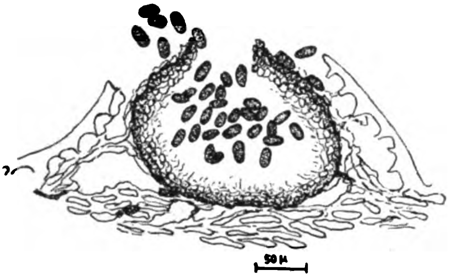
Sphaeropsis malorum Peck is the well known fungus that causes the black rot of apples. It has been very fully described and it is only necessary to refer to the publications of others.

Peck[1] described the fungus and gave diagrammatic illustrations of the spores, pycnidia and appearance of the apple.

Considerable work has been done to show the identity of the fungus with *Macrophoma malorum*[2] and *Sphaeropsis rhoina.*[3]

Paddock[4] proved the identity of the fungus causing the black rot and the canker of apples and also made a large number of cross inoculations with *Sphaeropsis malorum* and other *Sphaeropses* which show that the size of the spores varies with the host work on the pycnidial form. He shows illustrations of cankered limbs, sections of pycnidia from cankered limbs, spores, etc., but his illustrations are quite diagrammatic.

Kinney[6] gives a good description of the fungus and illustrations of spores and of rotting apples; and most of the Experiment Station publications mention the disease, giving cuts of rotted apples, cankered limbs, etc., for the macroscopic recognition of the disease. Where the minute structure is spoken of at



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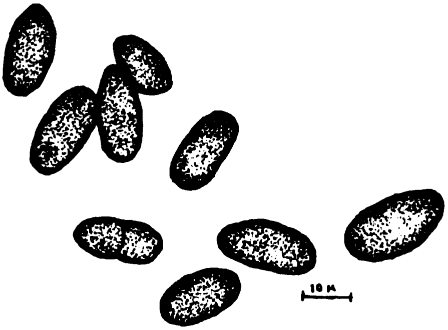

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FIG. 1.—Section of *Sphaeropsis malorum* pycnidium taken from a green apple mummy, illustrating typical pycnidia with oval spores.

FIG. 2.—Spores from the same apple.

all, mention is made of the oval or egg-shaped spores and the broad ostiole of the pycnidia.

Longyear[7] gives a detailed drawing of a pycnidium and spores and a brief, very careful description of the fungus and of the diseases caused by it.

One form of the *Sphaeropsis* under consideration agrees perfectly with this description.

Stevens[8] and others mention its attacks upon green fruit. This has been observed very commonly by the writer, as many green apples mummied by the fungus are found during the winter. In sections of such apples the fungus filaments do not seem to penetrate deeply into the tissues of the apple.

All who have given careful study to the fungus found oval or egg-shaped spores 20-25 microns by 10-11 microns and a broadly conical pycnidium with an ostiole corresponding with Saccardo's description. (Figs. 1 and 2.)

THE NEW FORM OF *SPHAEROPSIS.*

The new form of *Sphaeropsis* is much the more common, seemingly. It was first isolated from an apple badly affected with black rot in the fall of 1906, and has since been isolated from other similar apples. In every case the same characteristics have been observed.

CULTURAL CHARACTERISTICS.

The fungus has been grown upon all the common culture media (glucose agar, glycerine agar, plain agar, apple agar, gelatin, Pasteur's solution, corn-meal, potato, etc.). In all cases it has produced the same type of growth, but the growth has been most vigorous upon glucose agar, potato, and corn-meal. The growth is cottony and at first of a slightly grayish-white color. Soon near the surface of the medium the fungus threads begin to turn dark and the culture assumes a dark brown or blackish hue when viewed from the under surface. The color spreads rapidly thru aerial hyphae and all become darker, the extreme surface hyphae alone remaining a light gray color.

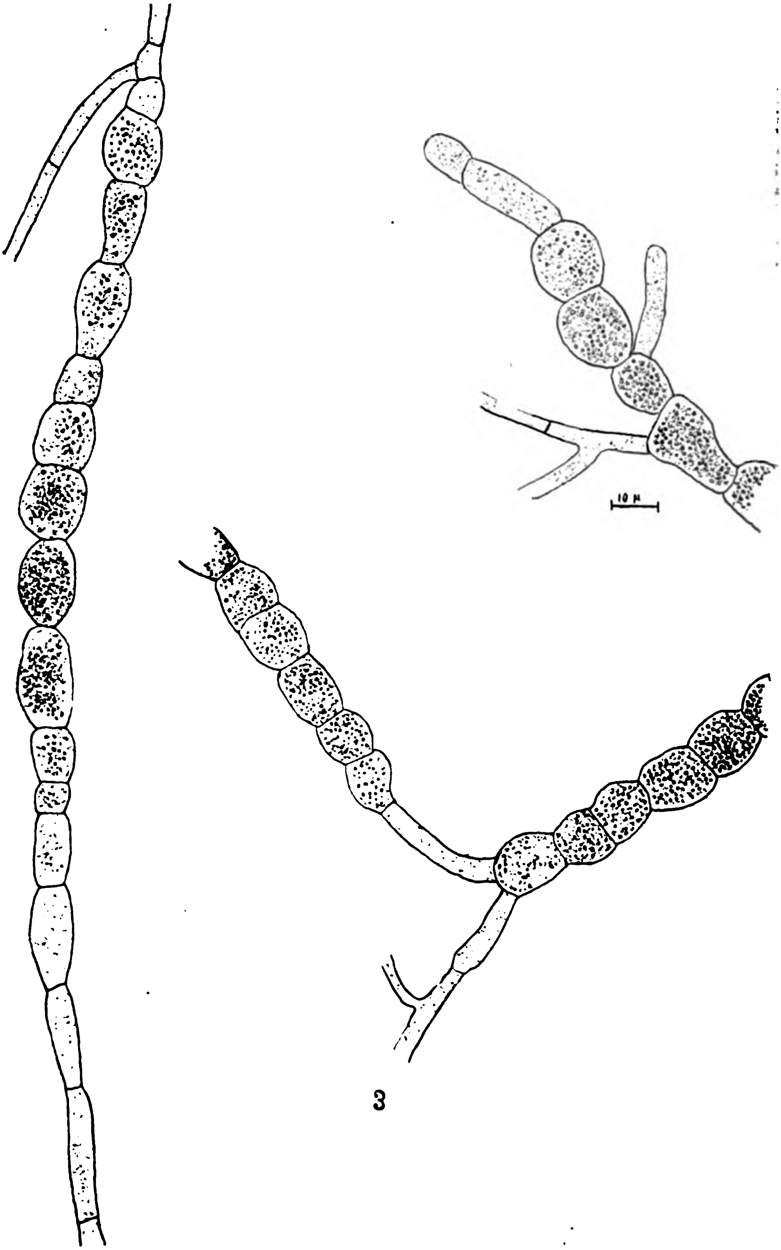

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Fig. 3.—Enlarged cells found in filaments of the new form as seen in hanging drops.

The fungus hyphae are normally about 3-6 microns in diameter, but often, in examining the apple tissue in which the fungus was growing, very much enlarged cells were observed. Similar cells were obtained in great numbers in hanging drops made of glucose agar, Pasteur's solution, etc. This peculiar formation is shown in figure 3. The walls of these enlarged cells are slightly thicker and the contents very much more granular.

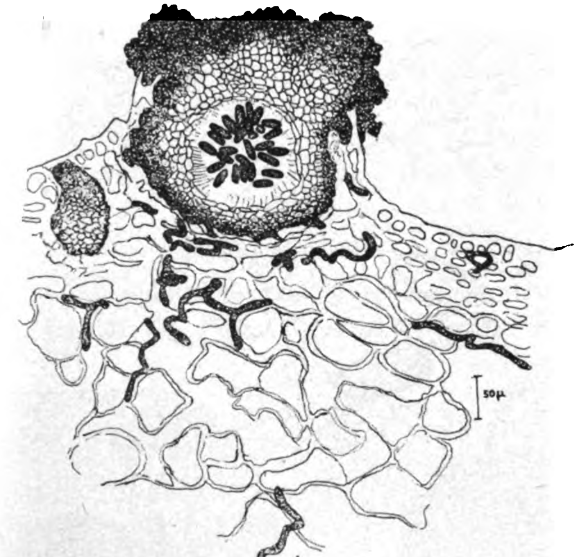
Upon none of the media used have pycnidia ever been found, but sclerotium-like bodies resembling pycnidia were often developed.

INOCULATIONS.

Repeated inoculations were tried in apples, and in every case the black rot was developed. The apples used were first wrapped in absorbent cotton wet with a 1-1000 solution of corrosive sublimate ($HgCl_2$) for a short time and then placed in a sterile damp chamber. Two apples were placed in the same chamber, one of which was simply punctured, while the other was inoculated with the hyphae of the fungus.

The inoculated apples began to rot around the inoculated spot in a few days and the rot spread very rapidly thru the entire apple. The rotting was much the same as for *Sphaeropsis malorum,* but more rapid. The apples at first turned brown with a blackish discoloration under the skin. Gradually they grew darker and became much wrinkled and shrunken black mummies. Examinations of the decayed tissue and of sections of the rotted parts seem to indicate that the growth of the fungus is largely intercellular.

No definite experiments were carried on to determine the mode of infection of the apples, but it seems evident that the fungus filaments have the power of penetrating the epidermis of the apple, as the check apples would become infected at the point of contact if allowed to touch the inoculated apples after they became badly rotted.



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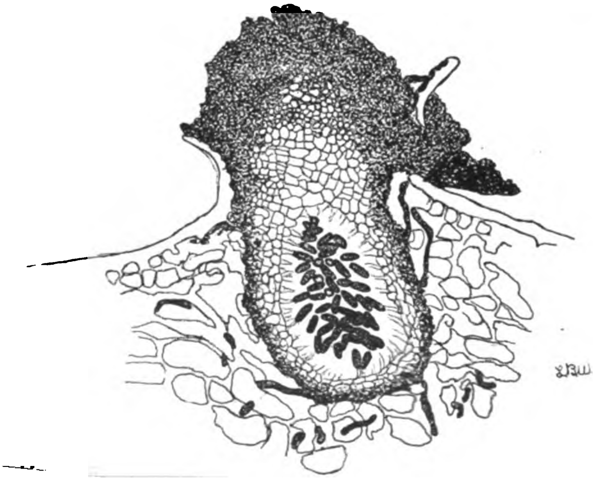

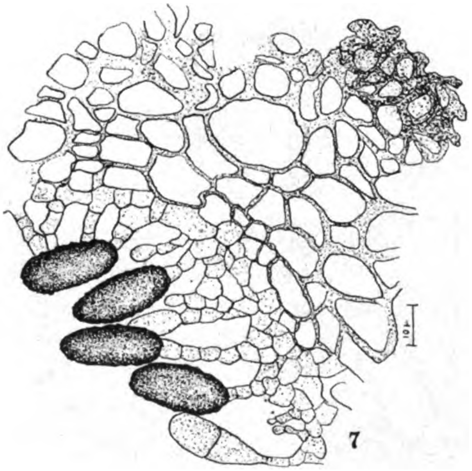

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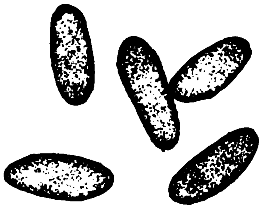

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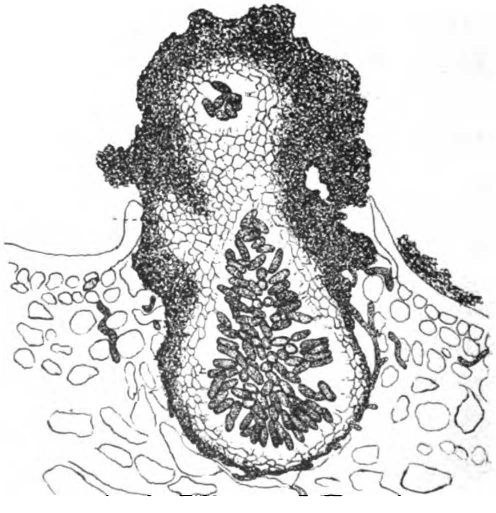

The pycnidia begin to form very soon after the rot has spread thru the apple and can be easily seen just under the surface of the epidermis. They gradually force their way thru the skin and appear as rough black spots on the apple. Besides these pycnidia many sclerotia-like masses of hyphae form upon the apple. These resemble the pycnidia so closely that the difference can only be detected by the aid of the microscope.

SECTIONS.

Serial sections of several hundred of these pycnidia taken from various inoculations, from different cultures, were examined to show the exact formation of the pycnidia, but in no case was an ostiole found. Instead of an ostiole the pycnidium was almost always very much thicker on the outer surface than on the inner. Figures 4, 5 and 6 show typical pycnidia. Dark brown one-celled spores were found in the pycnidia, but the spores were much longer than the spores described for *Sphaeropsis malorum.* The average spores were about 28-30 microns long and 10-12 microns wide, while many spores were as much as 33 microns long. The very smallest spore found was 23 microns long. Figure 7 shows the detail of the spore-bearing surface, and figure 8, mature spores from fresh material.

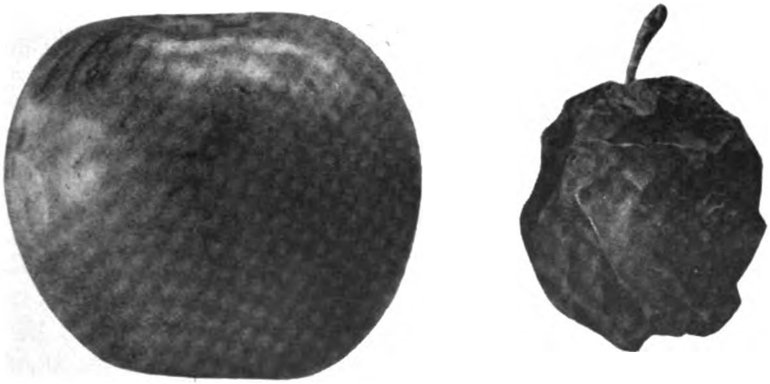

FIG. 9.—Photograph showing *Sphaeropsis* mummy and a check apple.

Thinking that possibly the slightly abnormal conditions in a damp chamber might affect the pycnidial form, sections were made of storage apples and of mummies wintered in the open that were affected with the black rot. The same pycnidial form was observed in all the apples that had pycnidia with long spores, while in those having the typical egg-shaped spores the ostiole was always very conspicuous. In a few cases on half-grown apple mummies the pycnidia containing long spores were but little thicker on the outer surface and it seemed possible that an ostiole might exist, but in examining dozens of sections none were found.

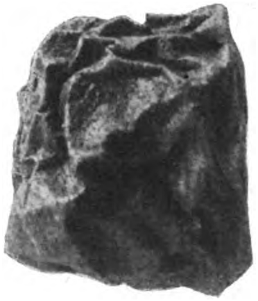

FIG. 10. — *Sphaeropsis* mummy, showing pycnidia.

The size of the pycnidia varied very greatly in the two forms, as is shown by figures 1, 4, 5 and 6, as both forms are drawn under the same magnification.

EXTENT OF INJURY.

So far as it has been observed the long-spored form seems to be a much more vigorous grower and to do much more damage than has been described for *Sphaeropsis malorum*.

In one orchard reported near Blair, Washington County, a large per cent of the apples rotted on the trees from the attack of the fungus.

DISTINCTIONS.

The distinctions between the two fungi can be briefly summed up as follows:

	Sphaeropsis malorum.	New Form.
Size of spore:		
Largest	25 x 12 microns	33 x 10 microns
Smallest	15 x 10 microns	23 x 10 microns
Average	19-20 x 10-12 microns	27-31 x 10-12 microns
Vertical diameter of pycnidia	169-223 microns	300-600 microns
Horizontal diameter of pycnidia	169-225 microns	150-375 microns
Sclerotium-like development	None	Very abundant
Ostiole	Broad, always present	None found
Pycnidial walls	Thin	Thick

SPECIES IDENTITY.

Whether the long-spored form should be considered a new species or a form of *Sphaeropsis malorum* is not determined.

In examining apples rotted by *Sphaeropsis,* none of the typical pycnidia and spores were found till very recently. These were found upon very small green apple mummies. All the other material examined was from ripe or half-grown apples.

Paddock[4] from his experiments in cross inoculations with *Sphaeropses* concludes that the size of the spore varies with the host.

If the spore size varies with the host, it seems possible that the spore size might vary when grown upon green and mature fruit. And if the spore size varies with the host it would seem quite probable that the pycnidium also might vary. Whether this is true or not can only be determined by further experiments with cultures and inoculations.

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SEED TREATMENT FOR THE SMUTS OF WINTER BARLEY.

BY F. D. HEALD IN COOPERATION WITH THE DEPARTMENT OF FIELD CROPS.

INTRODUCTION.

Winter barley has been grown on the Experiment Station plats during the past three years and has given a high yield, altho it has been badly infected with smut. The plat grown in 1905 showed 10 per cent of smut as determined by actual count, while in 1906 the count gave 15 per cent. The per cent of smut shown by a count does not indicate the exact per cent of loss by reduction of yield, but is generally somewhat greater than the per cent of loss.

Since seed treatment of barley for smuts has not been as satisfactory as in some other cereals it was deemed advisable to compare some of the different methods and to try a number of modifications. The results of the treatments will be given in the following pages.

DESCRIPTION OF THE BARLEY SMUTS.

Barley is affected by two different species of smuts: the *covered smut* and the *naked smut*. Both of these smuts were present in the field in the season of 1906. The covered smut (fig. 2). In the younger stages of the disease the awns still persist and they may remain till harvest time, altho in many cases they are broken off (fig. 2), while the thin membrane enclosing the smut masses may be more or less ruptured, exposing the purple-black spore-masses (fig. 2). Under the influence of heavy winds

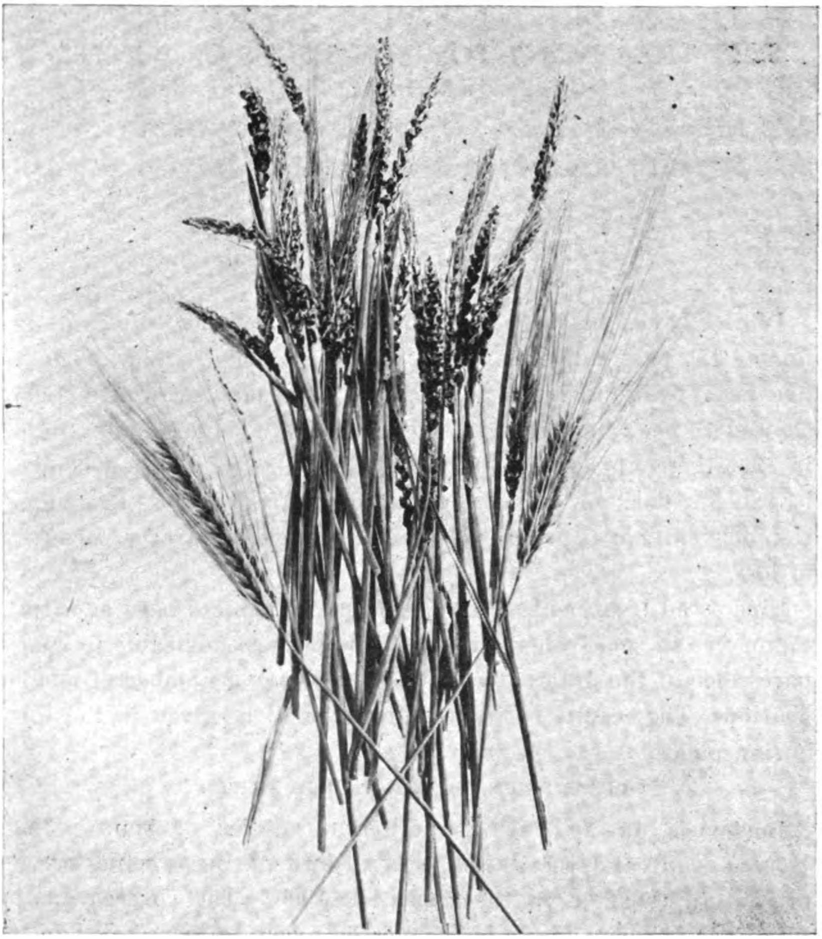


FIG. 1.—A bundle of smutted heads for comparison with two normal heads.

which prevail under Nebraska conditions, some of the spore-masses that become exposed may be considerably dissipated so that the heads have somewhat the appearance of the heads affected by the other species (fig. 3).

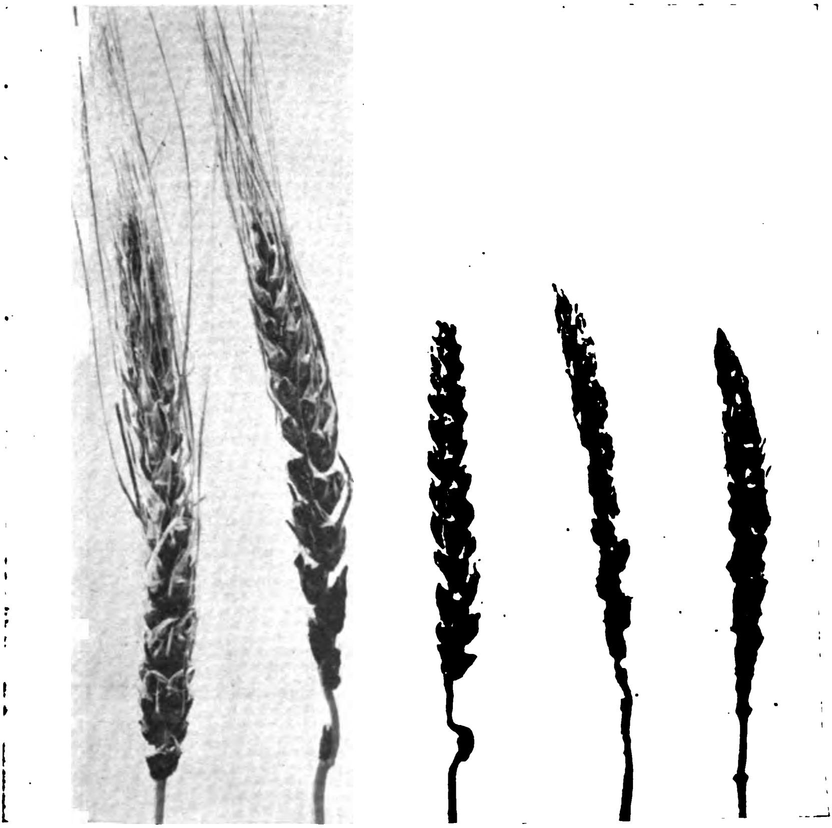


FIG. 2.—Heads of barley affected with the covered smut.

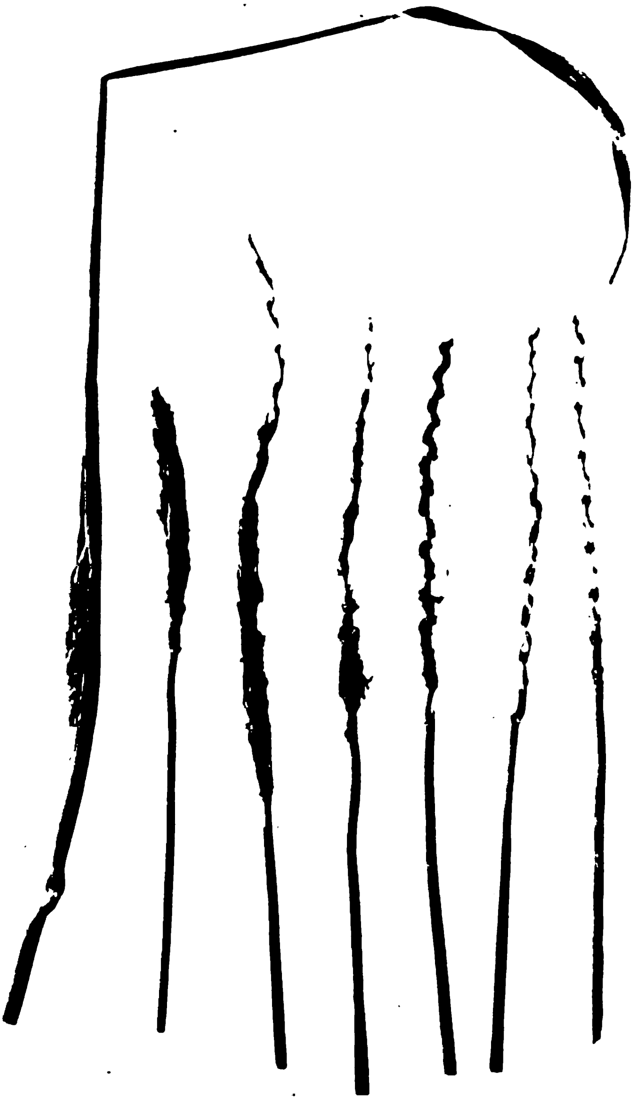


FIG. 3.—Heads of barley affected with the naked smut.

given in the following counts which may be considered fairly typical:

No. of plant.	No. smutted heads.	No. of heads free from smut.
1	10	4
2	3	5
3	7	6
4	9	0
5	3	0
6	9	3
7	4	0
8	6	4
9	4	3
10	6	2

In the naked smut the entire heads are also destroyed but they have an entirely different appearance from heads affected by the covered smut (fig. 3). When the head is just emerging from the leaf-sheath the smut-masses are covered with a thin membrane, but this membrane soon becomes ruptured and the spore-masses are rapidly dissipated. The awns never develop, and with the dissipation of the spore-masses the naked central axis of the head is all that remains at harvest time, and even this is frequently broken off at its junction with the stem. The stems which produce smutted heads are frequently three to six inches taller than the normal ones, and consequently are easily discernible.

THE TREATMENTS CARRIED OUT.

The different kinds of seed treatment used were the following:

(a) *The formalin steep.*—Four different strengths of formalin solution were employed:

Plat 2, 1 pint to 10 gallons water.
Plat 3, 1 pint to 15 gallons water.
Plat 4, 1 pint to 20 gallons water.
Plat 5, 1 pint to 25 gallons water.

The seed to be treated was placed in a coarse sack and submerged in the solution for ten minutes and then removed and allowed to drain to remove the excess of the solution. It was then emptied in a heap and covered with wet sacks for two hours, after which it was spread out to dry.

(b) *The modified formalin steep.*—The seed used for Plat 6 was first soaked in cold water for four hours and then set away in the wet sack for eight hours longer. At the end of this time it was treated with formalin solution, 1 pint to 36 gallons, using the same method as employed for the normal treatment (a).

(c) *The hot-water treatment.*—The seed used for Plat 8 was given the common hot-water treatment. It was soaked 4 hours in cold water and set away in the wet sack for 4 hours more. It was then warmed by submerging in water at 110° to 120° F. for a few minutes, after which it was immersed in hot water, 126° to 130° F. for five minutes and then spread out to dry.

(d) *Corrosive sublimate steep.*—Two different strengths of corrosive sublimate were used:

Plat 9, 3 parts corrosive sublimate to 1000 parts water.

Plat 10, 1½ parts corrosive sublimate to 1000 parts water.

The seed was soaked for fifteen minutes in the solution and then spread out to dry.

(e) *Copper sulphate steep.*—Two different copper treatments were employed, the first of which may be called the *normal* while the second may be called the *modified.*

Plat 11.—The seed was immersed in copper solution (1 pound to 24 gallons of water) for 12 hours, then in lime water (1 pound to 10 gallons) for five minutes, after which it was spread out to dry.

Plat 12.—The seed was soaked in water for six hours, then in copper solution (1 pound to 18 gallons water) for six hours, followed by five minutes in lime water, after which it was dried in the usual manner.

All of the seed treated was dried sufficiently to check germinaof untreated seed were used, the location of which is shown in the following diagram:

	1	2	3	4	5	6	7	8	9	10	11	12	13	
West	Control	Formalin 1-10	Formalin 1-15	Formalin 1-20	Formalin 1-25	Modified Formalin	Control	Hot Water	Corrosive Sublimate 3-1,000	Corrosive Sublimate 1½-1,000	Copper Sulphate Normal	Copper Sulphate Modified	Control	**East**

Effect of Treatment Upon Germination and Vigor of Growth.

The per cent of germination was lessened by all of the treatments employed except in the hot water treated seed which showed a perfect germination as contrasted with 97 per cent for the untreated seed used in the check plats. The per cent of germination was reduced to 40 per cent by formalin 1-10, and to 70 per cent by 1-15. The vigor of germination was also very much lessened, and the appearance of Plat No. 2 was very poor when examined on October 8, 1906. Not only were the plants smaller

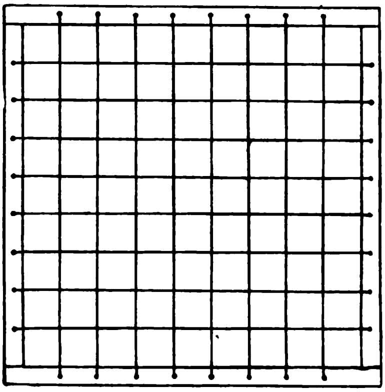


Fig. 4—Quadrat frame, enclosing one square yard, with cross wires at regular intervals.

but the stand showed less than half the number of plants in any of the other plats. The amount of seed used on the different plats was made to accord as nearly as practical with the germination per cent, so that the rate of seeding varied from two to four bushels per acre. In order to determine to what extent the rate of seeding employed gave a uniform and equal stand in the different plats, careful counts were made on October 8th. For this purpose a quadrat frame (fig. 4) enclosing one square yard was employed, and the figures given are the result of three counts for each plat. The following table will give the summary of the records for germination, rate of seeding, number of plants per square yard, per cent of smut, and yield:

TABLE I.—*Winter barley experiments.*

Plat No.	TREATMENT.	Germination of seeds.	Rate of seeding.	No. of plants per sq. yd. on Oct. 8.	Smut.	Yield.
		Per cent.	*Bushels.*		*Per cent.*	*Bushels.*
1	Untreated	97.0	2	188	*30.06*	55.60
2	Formalin 1 to 10	40.0	4	62	1.57	67.60
3	Formalin 1 to 15	70.0	3	151	1.04	77.28
4	Formalin 1 to 20	84.8	2½	187	1.28	73.20
5	Formalin 1 to 25	87.0	2½	194	0.50	73.80
6	Formalin (modified)	93.5	2	142	0.93	70.40
7	Untreated	97.0	2	185	*24.20*	58.74
8	Hot water	100.0	2	159	0.72	72.80
9	Corrosive sublimate 3–1000	65.2	3	228	1.29	71.20
10	Corrosive sublimate 1½–1000	81.3	2½	189	2.91	70.80
11	$CuSo_4$ (normal)	86.8	2½	202	0.56	70.60
12	$CuSo_4$ (modified)	93.8	2½	138	0.73	68.00
13	Untreated	97.0	2	172	*44.80*	58.74

The per cent of smut was determined for each plat by counting the number of smutted and unsmutted heads in three complete drills running the entire length of each plat. The total number of heads counted for each drill varied from 2,220 to 3,375. It was believed that this method would give a much more accurate estimate of the per cent of smut than either the staked quadrat or the quadrat frame method, which are better adapted for use under general field conditions. The average yield for the control plats was 57.69 bushels, while the yields for treated plats ranged from 67.6 bushels to 77.28 bushels, or an increase in yield per acre of 9.91 bushels in Plat 2, in which the treatment injured the germination per cent and vigor of growth, to 19.59 bushels in Plat 3 which gave the highest yield.

The treatments employed were more effective in preventing the covered smut than the naked smut. The relative efficiency is shown in the following table:

TABLE II.

Plat No.	Total percent of smut.	Per ct. of naked smut	Per ct. covered smut.
1	30.06		
2	1.57	95.6	4.4
3	1.044	98.0	2.0
4	1.283	90.0	10.0
5	0.506	100.0	0.0
6	0.93	97.2	2.8
7	24.20		
8	0.726	37.0	63.0
9	1 29	68.8	31.2
10	2.91	75.0	25.0
11	0.56	100.0	0.0
12	0.73	100.0	0.0
13	44.80		

It may be noted from this table that both of the copper treatments employed (Plats 11 and 12) were entirely effective in preventing the covered smut, while the naked smut was reduced to slightly more than a half of one per cent. The formalin treatment employed for Plat 5 (1 pint to 25 gallons) was equally effective and entirely prevented the covered smut, while the per cent of naked smut was the least obtained in any of the plats.

RECOMMENDATIONS.

The experiments show that barley smuts can be very greatly lessened by the use of the seed treatments employed. Of these treatments there may be recommended, as about equally effective:

1. Formalin steep, using 1 pint to 20-25 gallons of water.
2. The hot water treatment.
3. The copper sulphate steep.

THE MOLD OF MAPLE SYRUP.

BY F. D. HEALD AND VENUS W. POOL.

INTRODUCTION.

During the past few years a mold has frequently been observed growing upon various brands of maple syrup after they had been exposed in various containers to the air of the household for two weeks or more, and even in the original container if a small amount of the syrup had been removed. The mold generally appeared to be present in pure culture and its abundance and apparent peculiarities of nutrition led to the following study.

HISTORICAL.

Thru the researches of Eschenhagen,[1] Bruhne,[2] and Thiele,[3] it has been demonstrated that some fungi are capable of growing in very concentrated solutions of neutral, toxic, or nutritive substances having a high osmotic equivalent. Thiele in investigating the effect of concentration of medium upon the temperature maximum grew *Penicillium* on solutions containing as high as 70 per cent of grape sugar, and on a medium containing 25 per cent glycerin. *Aspergillus* was grown on medium containing 60 per cent glucose or 25 per cent glycerin. Pfeffer,[4] in referring to the work of Eschenhagen and Bruhne, states that the optimum per cent of grape sugar for the growth of fungi lies between 5-15 per cent but that some fungi can tolerate as high as 50-60 per cent. *Penicillium glaucum, Aspergillus niger* and other fungi are able to grow in solutions so concentrated that their turgor is equivalent to 38 per cent sodium nitrate, or 45 per cent potassium nitrate, which must produce an osmotic pressure in the cells equal to 157 atmospheres. The idea is expressed that fungi will withstand isotonic solutions of different non-toxic substances making the tolerance to concentrated solutions a matter of turgor adjustment. Raciborski[5] found that *Aspergillus glaucus* and a species of *Torula* could grow on saturated solutions of sodium nitrate, sodium chloride, or cane sugar, while *Torula* sp. grew slightly on a saturated solution of lithium chloride. Concentration of medium had but little effect upon the color of *Torula*, while the cells were reduced in size and shortened. *Aspergillus* failed to show normal color in the more concentrated solutions. That some fungi are able to tolerate a strong solution of a toxic substance is evident from the work of Rostrup.[6] According to this writer, *Penicillium glaucum* and a *Torula* species were found growing in a solution containing 14 per cent of copper sulphate.

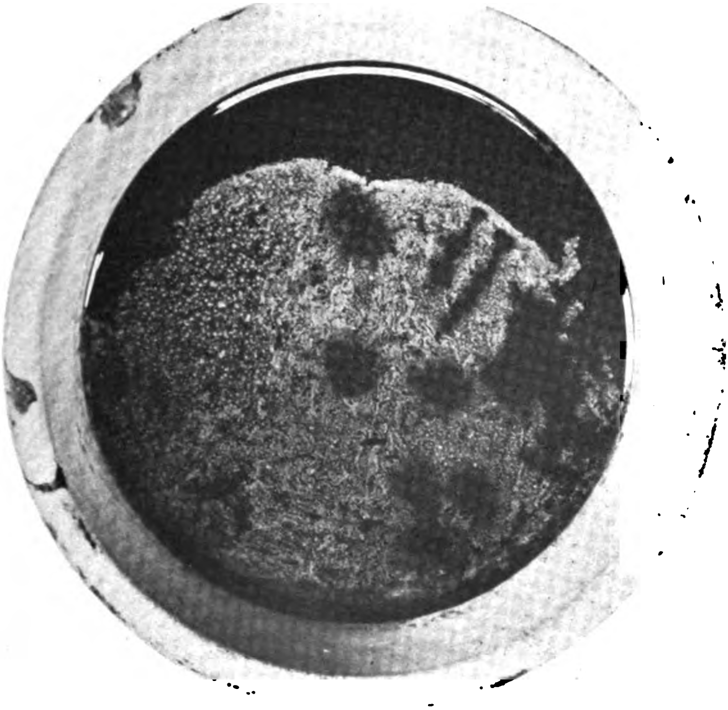
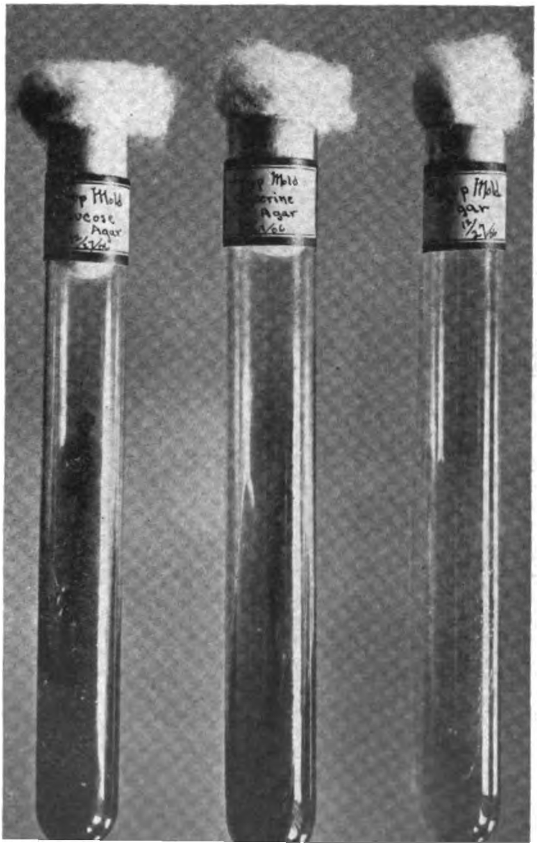


FIG. 1.—Natural growth of syrup mold upon maple syrup.

DESCRIPTION OF THE FUNGUS.

The syrup mold upon its natural substratum produces a thin, slightly powdery growth which either spreads quite uniformly



produced in abundance from elongated club-shaped conidiophores borne in rather dense tufts or acervuli. The spores are borne in chains, but the chains break up, upon mounting, into isolated spores and groups of two, three or four. The root-hyphae extending below the acervuli into the medium are septate and colorless, while the spore-producing branches and spores are of a pale smoky brown.

Our cultures of the syrup mold were examined by Prof. C. H. Peck and pronounced a new species of *Torula* closely related to *Torula sacchari-lactis* Oud.,[7] from which it differs in the average size and color of the spores and the ultimate branchlets and in the absence of the delicate prickles.

The species may appropriately be named *Torula saccharina.*

GROWTH IN CULTURES.

The syrup mold was easily isolated from its natural growth upon maple syrup since in all of the earlier studies it was the only mold present. For purposes of isolation, 3 per cent glucose agar (+10) was employed and the first sub-cultures made showed that the mold was unable to grow upon plain agar to any extent (fig. 2), indicating that it was not able to use peptone as a source of carbon. In this respect it differs from many other fungi[8] which grow well with peptone as the only source of carbon, altho both cane sugar and grape sugar present the carbon in a more easily assimilable form. The growth upon some common media is indicated in the following table:

Medium.	Culture.	Temperature.	First appearance of growth	Extent of growth.
Plain agar (+10)	Streak...	10° C.	None.	None.
Plain agar (+10).........	Streak...	18° C.	None.	None.
Plain agar (+10).........	Streak...	28° C.	19 days.	Few small white colonies, slight spore production.
3% Glucose agar (+10)	Streak...	10° C.	5 days.	12 days. Chocolate brown, tumid streak with abundant spore production.
3% Glucose agar (+10)..	Streak...	18° C.	24 hours.	15 days. Growth covering entire surface, chocolate brown, thick, somewhat folded, medium discolored.
3% Glucose agar (+10)..	Streak...	28° C.	24 hours. Slight whitish growth.	15 days. Growth covering entire surface, chocolate brown, thick, somewhat folded, medium discolored.
6% Glycerin agar (+10)	Streak...	28° C.	3 days.	19 days. Same as for glucose agar.
Potato (Irish)...........	Plate	28° C.	7 days. Distinct, small, brown colonies.	
Potato (sweet)..........	Plate	28° C.	48 hours. Distinct brown colonies.	

The preference of the mold for sugar as a source of carbon is shown in the above table, since only a slight growth occurred on plain agar at the end of 19 days, and also since the growth was much slower on glycerin agar than upon glucose agar. The same peculiarity was also shown by the quick germination and abundant growth on sweet potato, and the slow limited growth upon Irish potato.

The growth of the fungus was slightly retarded upon the sugar media by subjecting it to the temperature of the laboratory refrigerator (10° C.). This would indicate that syrup would mold becoming decidedly truncate pulvinate. They never increase greatly in size, varying from one-twelfth to one-eighth inch in diameter. The deep colonies remain small and colorless (fig. 3). The character of well-developed colonies is shown in the accompanying figures which represent sections of agar colonies. The center of the colony exhibits a loose network of hyphae, while the periphery shows a region of compact, parallel hyphae which ultimately ends in the spore-producing branches (figs. 4 and 5). The germination of the spores and the growth of the hyphae was observed in pure hanging-drop cultures. The growth from a single spore is shown in figure 6 from the beginning of germination to the formation of the first spores. A much-branched, sparingly septate mycelium is produced with chains of globular spores.

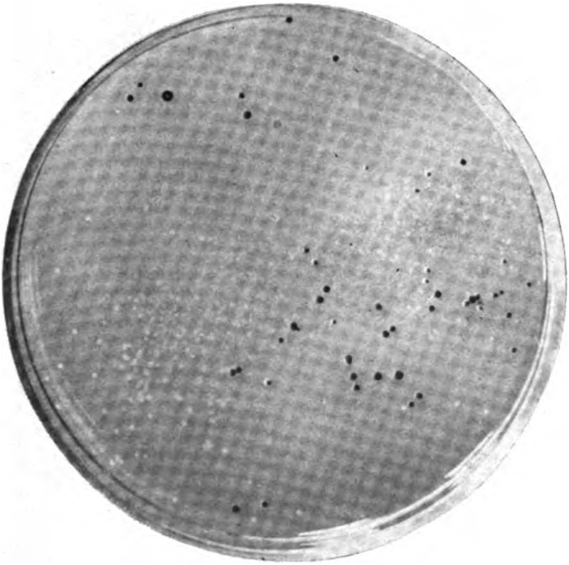
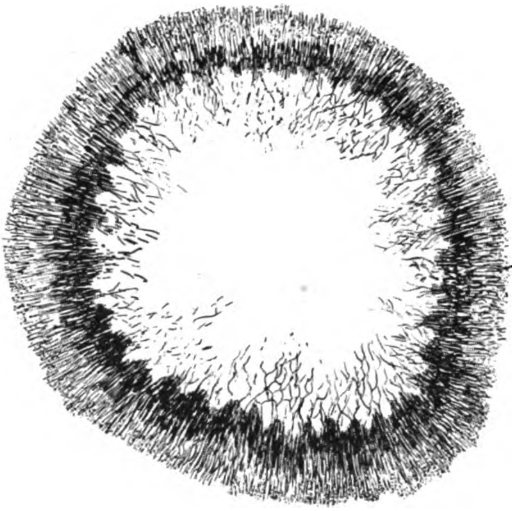


FIG. 3.—Appearance of superficial and deep colonies of the syrup mold. Glucose agar culture.

RELATION OF GROWTH TO CONCENTRATION OF SUGAR.

In order to determine the maximum concentration of sugar which would permit the growth of the mold, a series of cultures



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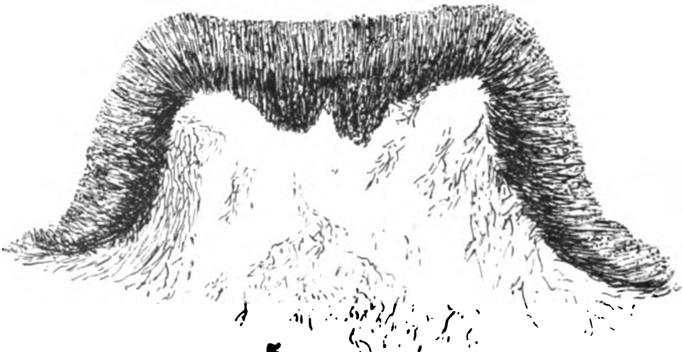

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Fig. 4.—Horizontal section of an agar plate colony.
Fig. 5.—Vertical section of an agar plate colony.

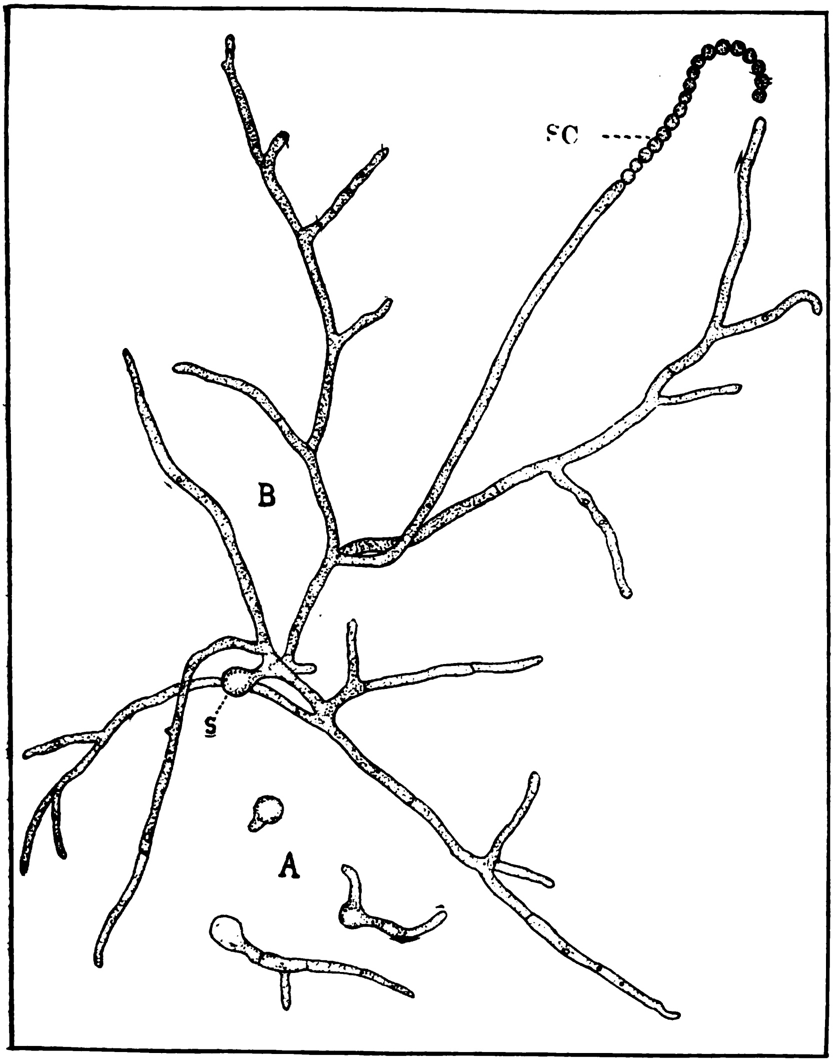

FIG. 6.—Germination of spores and formation of hyphae from hanging-drop cultures. A. Early stages in germination. B. The growth from a single spore. S. The original spore. SC. The first spore chain.

was made using the normal Pasteur's solution, which contains 15 per cent of cane sugar, as a stock solution and increasing the amount of sugar to obtain the different concentrations. The following formula for Pasteur's solution was employed:

Cane sugar	150.0 grams
Ammonium tartrate	10.0 grams
Potassium phosphate	2.0 grams
Calcium phosphate	0.2 grams
Magnesium sulphate	0.2 grams
Water (distilled)	837.6 grams
	1000.0 grams

The cultures were made in 200 cc. Erlenmeyer flasks, and 100 cc. of the medium was employed in each case. The inoculation in each flask was made by adding a small colony from an agar plate culture to each flask, thus insuring a general and uniform infection. The result of the cultures and also a comparison with *Penicillium* is given in the following table:

28° C.	SYRUP MOLD.		*Penicillium.*	
Medium.	First appearance.	Extent of growth.	First appearance.	Extent of growth.
Pasteur's Solution. (Normal) 15% sugar.	3 days. Colonies at bottom of flask.	8 days. Growth at bottom of flask and a few surface colonies.	24 hours.	6 days. Surface covered with heavy folded greenish growth.
20% sugar.	3 days. See above.	7 days. Surface colonies somewhat larger, fairly numerous.	....	....
25% sugar.	3 days. Same as above; slightly more growth.	7 days. Colonies numerous, light brown scum over entire surface.	....	....
30% sugar.	2 days. Colonies floating on surface, light brown in color.	7 days. Entire surface covered with worm-like growth.	2 days. Surface ¼ covered.	6 days. Large, green, folded mass covers surface.
35% sugar.	2 days. Numerous colonies on surface.	7 days. Surface covered with completely merged colonies.	....	....
40% sugar.	2 days.	7 days. Surface covered. Colonies larger.	....	....
45% sugar.	....	....	2 days. Surface ¼ covered with thin growth.	6 days. Surface covered with creamy, somewhat folded mass.
50% sugar.	2 days.	6 days. Entire surface covered; growth piled up.	....	....
55% sugar.	2 days.	6 days. Entire surface covered. Colonies separate, slightly spreading.	....	....
60% sugar.	2 days. Surface colonies fewer, small, thin.	8 days. Mold covers entire surface; growth thin, brown.	2 days. Slight growth in the solution.	7 days. Growth white, smoothly covering surface.
65% sugar.	2 days. Whitish colonies floating on surface.	9 days. Surface covered with thin, spreading, light brown growth	6 days. Growth slight, thin, white.	12 days. Growth white, slightly folded; microscope showing no spores.
70% sugar.	3 days. One-half surface dotted with small whitish colonies.	9 days. Entire surface covered with spreading light brown growth.	6 days. Growth slight, just visible.	12 days. No practical difference from 6 days.
75% sugar.	3 days. Very few tiny white colonies on surface.	9 days. Entire surface dotted with light brown colonies. Colonies flat, spreading.	....	12 days. No growth.
80% sugar.	....	No growth. Colony used for inoculation then placed in gl. agar tube. Good growth in 7 days.	....	12 days. No growth.
"Canada Syrup."	3 days. Distinct, small white colonies.	15 days. Surface covered with light brown growth. Colonies thin, spreading, no depth.	....	15 days. No growth.

It may be noted from the above table that the growth of the syrup mold was slower and less pronounced in 15-20 per cent of sugar than in the higher concentrations, while the growth was not completely inhibited until a concentration of 80 per cent was reached. The character of growth upon the concentration of sugar from 60-75 per cent simulates very closely the growth in spontaneous molding and in the pure culture on Canada sap which was carried out for comparison. *Penicillium,* which is a common house mold, did not grow at all in 75 per cent sugar or in any of the maple syrups which were tested.

The inhibition of growth by 80 per cent sugar for the syrup mold and by 75 per cent for *Penicillium* is probably not due to the high osmotic value of the solution. The hydrostatic pressure in the cell-sap of the hyphae growing upon 75 per cent cane sugar must be equivalent to slightly over 50 atmospheres.[9] It is known that *Penicillium glaucum* and some other fungi[4] are capable of growing in solutions so concentrated that their turgor is equivalent to 45 per cent potassium nitrate or 157 atmospheres, hence the inhibition of growth by the high per cent of sugar is probably due to low per cent of water available rather than to the high osmotic value.

In a series of cultures in Pasteur's solution in which glucose was substituted for cane sugar, the *Torula* was able to grow in all concentrations from 15-80 per cent. The 80 per cent solution allowed only a few scattered colonies to develop. This shows also that the inhibition of growth is not due to the osmotic effect of the sugar, since glucose has nearly double the osmotic value of cane sugar. In order to grow in 80 per cent glucose, the hyphae would be obliged to develop an internal osmotic pressure equal to 100 atmospheres.

It was impossible to determine the optimum sugar concentration for the growth of the syrup mold by ocular observations alone. An examination of the cultures indicated that the optimum concentration was between 30 and 50 per cent, but no closer estimate could be made. The optimum concentration was determined from a series of cultures in Erlenmeyer flasks in which the growth was removed at the end of seven days, carefully washed to remove the sugar and then dried to constant weight. The result of the determination is given in the following table:

Medium.	*Weight of growth.*	
Pasteur's Solution 15% sugar..........	0.190 grams	
Pasteur's Solution 25% sugar..........	0.218 grams	
Pasteur's Solution 35% sugar..........	0.261 grams	
Pasteur's Solution 45% sugar..........	0.293 grams	*Optimum*
Pasteur's Solution 55% sugar..........	0.270 grams	
Pasteur's Solution 65% sugar..........	0.075 grams	
Pasteur's Solution 75% sugar..........	0.116 grams	

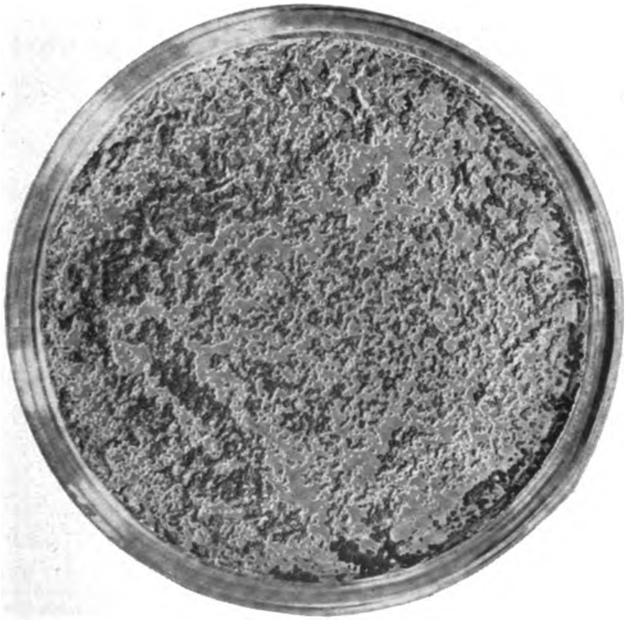

FIG. 7.—Growth of the syrup mold on Pasteur's solution containing 45 per cent cane sugar.

It may be noted from this table that the greatest growth re-

EFFECT OF CONCENTRATION OF SUGAR ON SPORE SIZE.

The concentration of sugar to which the *Torula* was exposed in cultures in Pasteur's solution had little effect upon the size of either spores or hyphae. The following table gives the average results from a large number of measurements:

Pasteur's Solution.	*Spores.*	*Hyphae.*
15% cane sugar..........	3.01 microns	2.58 microns
30% cane sugar..........	2.95 microns	2.58 microns
45% cane sugar..........	3.02 microns	2.58 microns
60% cane sugar..........	3.09 microns	2.58 microns
75% cane sugar..........	3.07 microns	2.58 microns
Canada sap...............	2.75 microns	2.00 microns

EFFECT OF FORM OF NITROGEN ON GROWTH.

A series of cultures was carried out to test the effect of the form of nitrogen on the character of the growth of the syrup mold, and *Penicillium* was used also for comparison. The following substances were substituted in Pasteur's solution for the ammonium tartrate: (KNO_3) potassium nitrate, (NH_4NO_3) ammonium nitrate, and (KCl) potassium chloride. The result is given in the appended table:

28° C.	SYRUP MOLD.		*Penicillium.*	
Media.	First appearance.	Extent of growth.	First appearance.	Extent of growth.
Variations in Pasteur's solution:				
1. KNO_3 substituted for NH_4 tartrate.	5 days. Surface dotted with small whitish colonies.	8 days. No change.	5 days. White growth — on surface and in medium.	8 days. Surface covered with folded white growth.
2. NH_4NO_3 substituted for NH_4	5 days. Colonies light brown, surface covered, di-	8 days. Color does not become dark	5 days. Growth more nearly resembles NH_4 tar-	8 days. Growth folded, not so heavy as on

chloride, which furnishes no nitrogen, was but slightly less than in potassium nitrate.

ANALYSES OF SYRUPS.*

In order to determine whether the molding of the different kinds of syrup was due to the low sugar content, a number of well-known commercial brands were obtained for analysis. These samples, which were in either tin or glass containers and sold for 25 to 45 cents each, have been given a sample number. The manufacturer's name is recorded with the sample number in the records but will not be repeated in this article. The amount of reducing sugars and sucrose in each sample was determined as recorded in the following table:

Sample Number.	Reducing sugars in 100 cc.	Sucrose in 100 cc.	Total sugar.	28° C. Time required for mold to cover surface after inoculation.
1 maple. ..	2.32	57.36	59.68	11 days.
2 maple.....	....	....	....	12 days.
3 maple.....	7.20	59.92	67.12	15 days.
4 maple.....	4.04	59 30	63 34	14 days (few colonies only).
5 maple.....	28.36	38.32	66.68	15 days.
6 maple.....	21.08	40.27	61.35	12 days.
7 maple. ..	4.36	52.70	57.06	11 days.
8 maple.....	4.74	51.25	55.99	11 days.
9 maple.....	13.61	51.45	65.06	13 days.

It may be seen from the above table that none of the syrups analyzed contained a sufficient sugar content to prevent the growth of the *Torula,* but it may be noted that the samples which contained the highest total sugar molded more slowly.

Some experiments were carried out to determine the effect of increasing the sugar content upon the molding. For example, by increasing the total sugar content of sample number 3 to 76 per cent by addition of cane sugar, the growth of the *Torula* was very nearly inhibited, only a very slight growth resulting. The per cent of sugar which will prevent or inhibit the growth of the *Torula* lies between 75 and 80 per cent (see table, p. 64); hence it is evident that the market articles should be made more concentrated than is the common practice. If the syrups are made sufficiently concentrated little or no growth of mold is likely to occur.

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*Furnished by Dr. F. J. Alway.

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A ROT OF GRAPES DUE TO *PESTALOZZIA UVICOLA* SPEGAZ.

BY F. A. WOLF.*

Some ripe grapes that were brought into the laboratory at the Nebraska Experiment Station in September, 1907, were covered with numberless black pustules protruding from the epidermis. A microscopic examination showed that the spores were those which characterize the genus *Pestalozzia.*

Two species of *Pestalozzia* have been described as occurring on the grape in the vineyards of France and Italy.[1] The one, *Pestalozzia thümenii* Spegaz., forms the larger, more numerous heaps. Its pustules are irregular in shape and the cuneiform spores have two hairs, one arising from the vertex and the other from the side. The other, *Pestalozzia uvicola* Spegaz., forms circular pustules and its fusiform spores bear three hairs at the apex. The Nebraska specimens agree in size and character of the spores with *Pestalozzia uvicola* Spegaz. No record has been found of the previous occurrence of this species in America.

Pestalozzia uvicola was first reported in September, 1877, by Spegazzini as being very destructive among the vineyards near Conegliano, Venetia. Von Thümen,[1] who first described this species, gives the characterization as follows: "The spores or conidia are mostly spindle-shaped, five celled; the three middle cells are olive brown, slightly constricted at the points of septation and generally provided with guttae. Both end cells are hyaline, as in other species of *Pestalozzia,* and more or less conical. The length of the spore is 35 microns, the breadth 8-10 microns. At the basal end is a crooked hyaline stalk of uniform thickness 25-30 microns long and 1 micron broad, while at the upper end are found three characteristic hairs or setae which are colorless, 8-10 microns in length and 1 micron in thickness."

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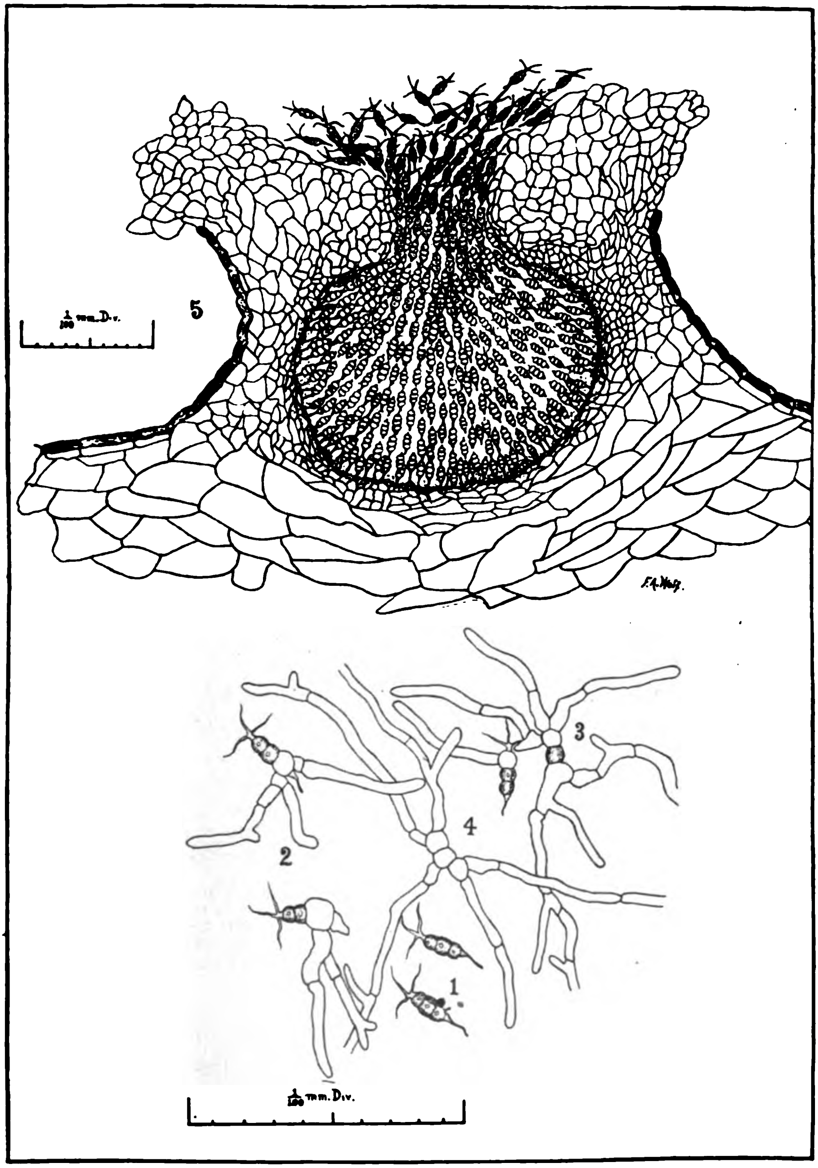
In hanging drop-cultures, in which the medium was glucose agar with a reaction +10, these spores were found to germinate readily and to produce hyphae from all the dark cells, whereas in the species on rotting strawberries the basal cell alone is known to germinate. Not only was a single tube formed, but several from each cell seemed to be more typical and indicative of the intense vigor of the spores.

In order to determine something of the action of the rot, inoculations were made on two separate bunches of grapes in sterile moist-chambers. In one case hyphae from a pure culture of the fungus were used, and in the other spores from the rotted grapes. A sterile needle was used to puncture the grapes and convey the inoculum thru the puncture into the interior of the grape. All the noticeable effect in the succeeding weeks was that circular depressions occurred at the points of inoculation. After a time numerous pustules began to appear on the surface of the inoculated grapes. At the same time masses of spores were developed in the pure culture of the fungus as grown on glucose agar with the reaction +10. The only definiteness about their formation was that it was restricted to one or two places and not promiscuously over the hyphal surface.

Portions of grapes showing spore-producing pustules were imbedded in paraffin. Sections of the pustules did not show a structure as one would expect to find in the *Melanconiaceae,* to which illustrates a form very similar to those already mentioned. None mention a pycnidial structure for *Pestalozzia*.



In the sections of *Pestalozzia uvicola* the true pycnidial structure was easily demonstrated. The well-defined pycnidium protrudes thru the ruptured epidermis, pushing up the outer epidermal walls and expanding above them into a great mass of pseudo-parenchyma. A relatively narrow ostiole is left thru this pseudo-parenchymatous tissue thru which the spores escape. In some cases the pycnidia were more flat and open than the one in figure 5, yet in all we find that a definite conceptacle is formed by the false tissue within which the spores are formed.

Since it is so evident that this is typically a true pycnidium-forming fungus, we must slightly modify our views concerning its classification. Either it is not one of the *Melanconiaceae* or else the generic description is not adequate unless it is modified so as to include the range of types from the flat surface upon which the spores are formed beneath the epidermis, without any pseudo-parenchyma, to the one which forms a well-defined pycnidium. The latter would seem the less radical measure and could perhaps be easiest accomplished.

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EXPLANATION OF PLATE.

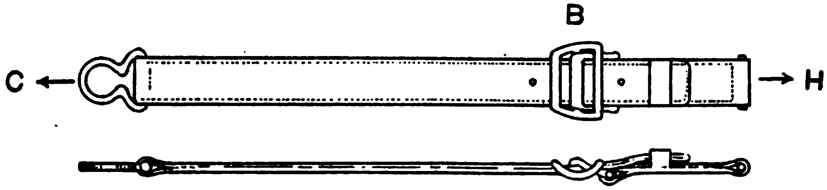
Fig. 1. Spores showing the five cells: the middle three brown, the basal hyaline, and the upper hyaline with three setae.

Fig. 2. Spores which have germinated from basal cell.

A STRENGTH TEST OF HARNESS LEATHER.

BY GEORGE R. CHATBURN.

A farm harness tug, new, with a hame tug, attached by means of the ordinary buckle and a cockeye, was placed in the testing machine and force continuously applied at the end of the hame tug H, and at the cockeye C, until the failure of the tug, which occurred by tearing the leather through the buckle hole at B.



Two tests were made, each of which failed in the same manner. The results were as follows:

First Test:	
Failure began by tearing at	1000 pounds
Maximum loading attained	1400 pounds
Second Test:	
Failure began at	1100 pounds
Maximum loading	1570 pounds
Average:	
Beginning of failure	1050 pounds
Maximum loading	1485 pounds

Since the tractive force necessary to haul a loaded wagon on an earth road which is in fairly good condition is about 100 pounds per ton, four tugs of this character would haul a load including the weight of the wagon of

$$\frac{1485\times4}{100}=59.4 \text{ tons.}$$

or with a factor of safety of ten, which is not any too large, the 1¾-inch tug is capable of safely hauling 5.94—that is, practically 6 tons.

On a macadam road this load could be doubled, and on a brick pavement quadrupled.

LOCO WEED POISONING IN HORSES.

BY A. T. PETERS AND L. B. STURDEVANT.

INTRODUCTION.

In July, 1906, the Department of Animal Pathology of the University of Nebraska began an experiment with loco weed poisoning in horses at Imperial, Nebraska. The work was carried on with the cooperation of the Bureau of Plant Industry of the United States Department of Agriculture and with the assistance also of the citizens of Chase county, Nebraska. Dr. C. Dwight Marsh of the Bureau of Plant Industry had already begun his investigations on the loco weed early in 1905, at Hugo, Colorado, and was thus in a position to aid us very materially. His advice from time to time saved us without doubt from many serious mistakes. For the animals used in the experiments and for the use of the fair grounds at Imperial, we are indebted to the Chase county citizens.

The thousands of dollars lost annually by ranchmen in the western part of this state on account of loco weed poisoning in horses, cattle, and sheep was sufficient reason for starting the experiment. The summer of 1906 seemed to be a most opportune time for this research, since the Bureau of Plant Industry had already begun investigations along this line, and we could profit by their past experience.

SYMPTOMS AS HITHERTO DESCRIBED.

The symptoms of loco weed poisoning as described in 1901 by V. K. Chestnut and E. V. Wilcox in Bulletin No. 26 of the Department of Agriculture, Division of Botany, from which we take the liberty of quoting, were as follows:

"Perhaps the most characteristic are those of cerebral origin, consisting in peculiar irregularities in gait and action, which may be compared to a drunken condition in men. Sheep and other animals affected by this disease are commonly said to be crazy or locoed. The cerebral disturbance may consist in an impairment of the function of the special senses, or in improperly regulated motor impulses which produce a more or less pronounced incoördination of muscular movement. Sight is frequently impaired. In some cases the animal soon becomes totally blind. This condition is reached more often in acute cases than in chronic cases of loco disease. More frequently the animal simply sees incorrectly or makes errors in judgment of size or distance of objects. These errors in judgment of ocular perceptions are a common occurrence and are often so pronounced as to become ludicrous. A locoed horse upon being driven up to a gate may either attempt to jump over the crossbar, which is usually placed at the height of about 15 feet, or may lower his head from fear of striking it. Simple experiments indicate that both sheep and horses in a locoed condition frequently mistake harmless things for dangerous enemies. In horses which are affected with the chronic form of loco disease one has abundant opportunity to observe many peculiar and senseless actions which are evidently due to cerebral disease. Locoed horses are often used for both draft and driving purposes. Such horses may work or travel in a perfectly normal manner for days at a time. They frequently, however, run away or are attacked with kicking fits without any apparent external cause. Observations made on horses which are only slightly locoed indicate that they do at times become frightened by purely imaginary objects. This fright would seem, however, to be none the less real, since such horses often tremble or become covered with a cold sweat after these imaginary dangers are passed.

"The sense of hearing is frequently affected in locoed animals, as is easily demonstrated by simple experiments. The response to various sounds and noises is not always in accordance with the character or volume of the sound. At times a loud noise is unheeded, while at other times a slight noise of the same character may produce fright. The locoed animals are often unable to judge correctly the direction from which sounds come.

"Irregularities of the muscular movements of locoed animals may assume a variety of forms. The animal may simply carry its head in an extended or otherwise unnatural position. In some cases the arched carriage of the back is to be noticed with awkward movements of the legs. Trembling is a frequently noticed characteristic of the locoed animal. This may be confined to the legs, especially to the knees, or may involve all the voluntary muscles, and occurs in a most pronounced manner after any fright which the animal may have experienced. It is often observed of locoed horses that even when they are able to move forward with considerable precision they experience difficulty in backing."

THE PASTURES USED.

The pastures used and the land grazed over were practically all unbroken raw prairie. The most valuable wild grass found here for feed was *Agropyron glaucum,* since it grew in abundance in many places. *Schedonnardus paniculatus* and *Bouteloua oligostachya* were also very plentiful and readily eaten. *Lygodesmia juncea* was eaten about as readily as the grasses and was growing in large numbers everywhere. *Chaetochloa viridis* (green foxtail) was seen occasionally as was also *Cenchius tubuloides.* One species of *Aristida* was fairly abundant but not eaten after it had developed the "stickers," which the animals wished to avoid. Among the weeds not eaten by the horses the

FIRST ATTEMPT TO INDUCE LOCO-EATING HABIT.

The experiment was started on July 10, 1906, with three horses from Kilpatrick Brothers' ranch, located nine miles southwest of Imperial. These had been shipped in from Wyoming the previous winter and were rather wild but supposed to be halter-broken. They were in fair flesh. Three other horses were added to those above mentioned and an effort was made to induce these horses to acquire the loco habit by running in a pasture where loco weed was common.

From the first the animals were corralled at night and then, late in the morning, turned into the small pasture, which was hardly larger than a good-sized lot, containing two or three acres. This was with the hope that they would snap at the larger plants including the loco weed in order to quickly satisfy their first and most urgent pangs of hunger. This plan, however, is much more successful in cattle, where the immense size of the rumen demands a space-filling food. It could be noticed, however, that *Lygodesmia juncea* (the rush-like *Lygodesmia*) was eaten considerably oftener in the early morning than later in the day, probably because it is a fairly large weed and fills more space in the same grazing time than any of the grasses.

Of course the personal equation is too large for us to base any radical conclusions on the feeding habits of a half-dozen horses. This much, however, was plain, that when the grass gets very short, hunger will compel many horses to eat this weed. This much confirms the observations of the ranchmen who state that the habit is frequently formed in the early spring or late fall when the grass is short. It is advisable to give a small grain ration to horses turned out to pasture too early or kept in it too late in the fall so that their extreme hunger will not lead them to eat the loco weed. This custom is practiced by a few ranchmen in the western part of the state and with good results. A horse which, by reason of the short grass, nibbles loco weed for a few days, when transferred to good pasture persists in the loco-eating habit only for the first day or part of it. If compelled to eat loco for a longer time, the habit persists longer and may become permanent as we shall show. A very wet year will frequently produce a large number of locoed animals during the entire summer, probably because the loco plant is unusually succulent then and they get into the loco-eating habit even tho grass is abundant at that time.

On July 28th we abandoned the attempt to induce the loco-eating habit by corralling at night and turning the horses out late the following morning. We began "breaking" the animals into the habit one at a time by shutting them up in the corral and feeding them for a few days with the picked weed.

CASE OF HORSE NO. 1.

Horse No. 1 was a black filly, nearly two years old, which had broken her hip by a fall on the ice the preceding winter. This hip was now healed, so that it did not interfere with her gait. On being turned into the pasture when she was first received, July 10, 1906, she snapped at a loco plant as she walked along, getting a mouthful of the weed, which she ate. She subsequently acquired the loco-eating habit, but only after being "broken" into it, and is not further mentioned in this experiment, since she did not die from the effects of the loco.

CASE OF HORSE NO. 2.

Horse No. 2 was a black gelding, about seventeen months old, with a weak and lax fetlock joint on the left hind leg, which caused him considerable difficulty in using the foot. He ate a piece of dried loco weed in the pasture on July 21st but did not

31st 2½ pounds. He was then turned into the small pasture for the afternoon, when he was offered 2½ pounds of picked weed which was not very fresh and which he did not eat until corralled at 6 P. M. He was left in the corral over night, and the following day ate 6 pounds of the weed in the forenoon and 6 pounds in the afternoon, and was turned into the small pasture at 6 P. M. On August 2d he was corralled all day, eating 6 pounds of loco weed in the forenoon and 5 pounds in the afternoon, leaving about 1 pound uneaten. He was turned into the small pasture at night. On the 3d he was corralled all day and turned into the small pasture at night, eating 9 pounds of picked loco in the forenoon and 4 pounds in the afternoon. On August 4th he was corralled all day and the night following, eating 9 pounds of loco. Four pounds more, which was a little dirty, was offered him at 6 P. M. but was left till the next day, when it was washed to remove the dirt and was eaten during the forenoon. During the afternoon of August 5th he ate 5 pounds of loco and was turned into the small pasture at 5:30 P. M. with access to 5 pounds more loco, which was all eaten by the next morning. On August 6th he ate 13 pounds more of picked loco during the forenoon and on being corralled ate most of 6½ pounds placed there for another animal. He was turned into the small pasture for the night and left there during the day following, when he ate readily 5 pounds of loco in the forenoon and 5½ in the afternoon. On August 8th, while still in the small pasture, he ate 6 pounds of loco in the forenoon and 5 pounds in the evening and the following morning. The total amount of picked loco weed eaten from July 29th to August 8th over several more without paying any attention to them. From this time on he was fed with picked loco at intervals more or less irregularly because of the difficulty of getting the weed just when it was wanted. We had no way of measuring very accurately the amount of weed eaten on the prairie or in pasture, but weighed the picked weed as it was fed. We always tried to give all the horses on this experiment grass at frequent intervals, since there is very little nutritive material in the loco and the horses which do not have the loco habit do not eat loco except when forced to by hunger. From August 8th to August 13th, no picked loco was fed. From August 13th to 26th inclusive, 87 pounds of picked loco was fed to this horse. This was an average of about 6¼ pounds per day, but varied from 1 to 12 pounds per day. It was impossible to make the daily ration always the same, owing to the difficulty in securing the picked weed just when it was wanted and the further difficulties in keeping it fresh. These were overcome somewhat by dipping the loco in water or sprinkling with water and keeping it piled in the shade and covered with a wet cloth. From August 27th to September 15th he was herded on the prairie most of the time and received no picked loco except 14 pounds on September 6th and 7th. From September 15th to 21st inclusive, he ate 66 pounds of picked loco, an average of 9½ pounds daily. On September 26th he was fed 10 pounds of loco, on the 27th 21 pounds, on the 28th 6 pounds, and was found dead on the morning of September 29th. The total amount of picked loco consumed by this horse was 322 pounds. The first loco fed was eaten 62 days before death occurred.

SYMPTOMS OF HORSE NO. 2.

The symptoms exhibited by Horse No. 2 above mentioned are came in his road and walking five or six feet out of his way to get some of them. On August 11th, when driven to the water tank, he walked clear around it before drinking. He ate a little picked weed which was being saved for another animal, before being discovered. He ate growing loco plants greedily, passing only a few. The swelling was now (August 11th) on both sides of the lower jaw, extending to the angle of the mouth on either side.

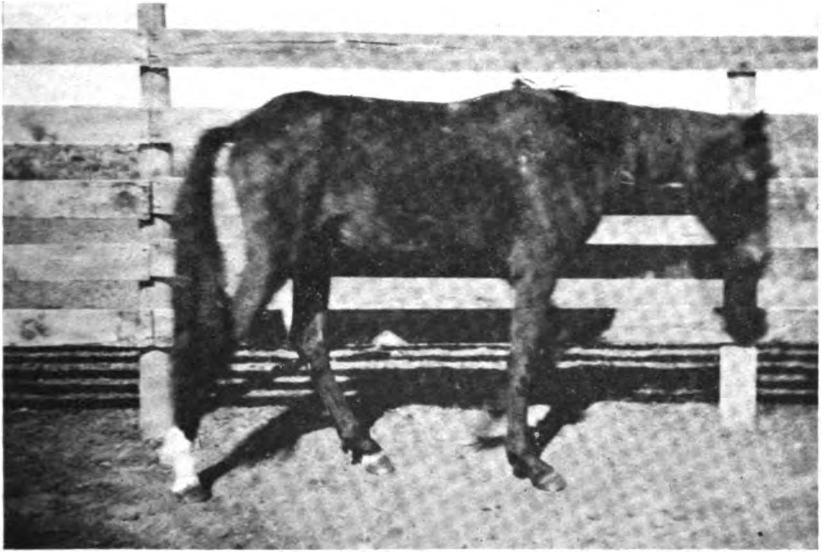


Fig. 1.—Horse No. 2, showing the "hanging" head.

The first place of swelling was not so prominent. On August 12th the swelling had disappeared. On August 14th the animal ate 4 pounds of picked loco readily in addition to that eaten while grazing. On August 15th he was offered picked loco twice but left most of it to go and look for the other horses. On August 16th some enlargement of the lymphatic glands of the lower jaw was first noticed. This enlargement continued till the time of his death. On this date he circled clear around the water tank and hesitated before drinking. He was still in fair flesh. At this time he began to show a more irritable disposition than formerly, biting at the other horses, especially when No. 3, the sorrel filly, happened to nibble at a pile of picked loco weed where he was eating. Altho he would leave a pile of picked weed occasionally, he always returned to drive off No. 3 when he saw her eating at his pile of loco. On August 19th he allowed one of the larger horses to feed off of the pile of picked loco without resenting it. In the afternoon when the attendant went to drive him to water he had a great fit of fright and trotted away in the opposite direction, snorting twice and at the same time lifting his fore feet very high and showing the characteristic loose-knee action with poor control of the carpal joint.

On August 22 No. 2 drove another horse away from the water pail by first squealing and then biting, and repeated this when the animal tried a second time to drink. A more glassy appearance of the eyes was first noticed on this day. When he arrived at the fair grounds toward evening he walked about as if expecting a ration of picked loco but lay down after being watered and when we left he whinnied after us. This tendency to notice us and show interest whenever we came around increased from this time on and the animal became much tamer than before. He frequently wanted also to stop at the place where he had been fed with picked loco. Stupidity became marked at this time also, the horse standing perfectly still for many minutes at a time. Despite this stupidity the animal exhibited signs of uneasiness, starting to walk many times without any object whatever in view, sometimes stopping soon, at other

On August 23d for the first time he allowed one of the smaller horses to eat at the same loco pile with him. On being caught with a rope he showed great excitement, the muscles of the shoulder and thigh quivered abnormally and he struck out once quickly and wildly with his left fore leg. While trotting he raised both fore and hind legs unusually high, flexion at the carpus being rather extreme. On August 24th he walked right by a narrowly opened gate, which had to be opened widely to get him thru. He now ate every loco plant which he came across. While drinking in the afternoon he leaned forward against the water tank, with his fore feet, especially the right, very much behind their normal position. On corralling him at night he stayed at the place where he was usually fed with loco weed.

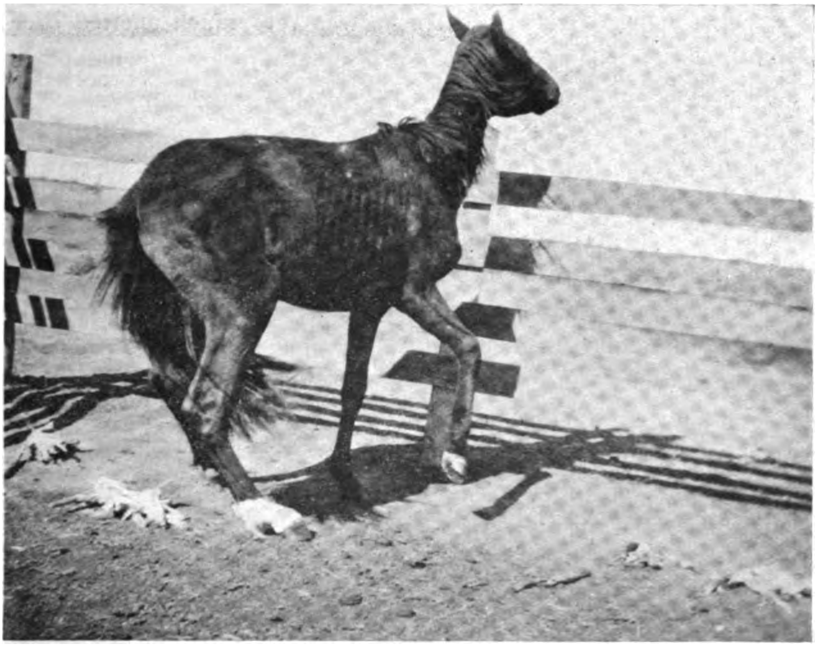


FIG. 2.—Horse No. 2, after being frightened from in front while walking along a fence.

On August 25th he was constantly running away from the pile of loco weed and then back to it again. This nervous or "uneasy" conduct of the animal increased from this time on. The horse would do one thing for awhile and then suddenly leave this and start something else. It was the same way with his grazing, feeding in one place for a short time, then walking to another at a distance of twenty or thirty feet from the first in an aimless way. On being driven to water he was very much excited over some sacks of loco weed that had been left in an unusual place in front of the water tank and rapidly walked back and forth before them. Later he tried to climb over the pipe, which ran from the windmill to the water tank, but gave it up and turned around to walk out from between the two. On August 26th he would eat loco weed from one's hand. He answered the neighing of another horse in a near-by pasture and walked over to where that animal was. He now walked about constantly, never still for more than a couple of minutes at a time. On this day he was frightened twice, once by some boys who were quiet and once by a sunflower moving in the wind. Like a normal horse he frequently failed to show fright where we might reasonably expect it or on the other hand showed it unexpectedly. In general he was frightened more often and more severely than a normal animal. On August 27th he ate mostly loco weed all day, hastening from one plant to another. Once, while grazing, the phalangeal joints of his left fore leg remained flexed for a half minute before he put any weight on them and thus straightened them. The up-and-down motion of his head was now excessive while walking. He came up to the writer once as if for loco weed perhaps, and from this time on he became tamer than ever. On August 29th all the animals drifted on a large patch of wild wheat grass and would not leave it until driven off. On which barked at the horses, as if, perhaps, to strike him, but the dog escaped. On September 3d and thereafter, the horses would go at once to the wheat grass and on being driven off would wander right back. One of them, however, toward the last, would leave the wheat grass to look for loco. All of them carried their heads slightly lower than normal horses and moved much more slowly.

Horse No. 2 was by nature inclined to stumble, but this tendency was apparently much increased by the influence of the loco as was also the case in the others. On September 4th he was found lying down on the prairie in the afternoon, and on being purposely frightened he arose at once, getting up like a cow, on the hind legs first. The hind legs are apparently less affected than the fore legs by the loco weed.

On September 5th the animals were driven under a large white sign with black letters on it. They never seemed to notice it at all altho they were driven under it several times during the summer. Sometimes one of them would shy at the gate which stood at one side but that was all. Horse No. 2 on September 8th left the water tank after drinking but immediately returned and drank again. This was unusual but constituted one of his symptoms of nervousness. By this time there was prominently developed the tendency to follow a road, a ditch, a railroad track, a fence, a buggy, or one of the other horses or even to go ahead in a straight line for many rods on the prairie apparently without reference to any particular end in view. In following a fence he would almost always go right by an open gate. He would persist in following a road or another horse with surprising stubbornness at times, it being a hard matter to make him go in any other direction. At other times, however, he would wander away, usually in search of loco, and remain alone all day, walking very slowly and standing still by turns, but when with the other horses would again show the tendency to follow them. The other animals from now on were less kindly disposed toward him. Occasionally he would show stubbornness also in wanting to remain out on the prairie when it was time for him to be driven home. His tendency to stumble was more pronounced at this time than ever. He would frequently fall to his knees, regaining his feet in a lively but very awkward manner. In crossing a railroad track or furrow he would raise his feet slowly and very high. This was especially true of his fore feet.

On September 14th he was first observed to void his urine without extruding the penis from the foreskin. Half a minute later the penis was extruded. At this time he walked right by a couple of pails of water and had to be driven back to them, when he drank a considerable quantity. He neighed as the buggy started away leaving him alone on the prairie. The next day he came back to the fair grounds of his own accord. His cheeks at the angle of the mouth appeared to be slightly swollen. From this time on the head was carried somewhat lower than normally.

On the 16th he came in answer when called from a distance of seven or eight rods. On being given a pail of water in the morning he made an awkward lunge forward, striking out with his fore feet but backing off suddenly as if scared. In this case no doubt he suddenly for the moment lost control of his legs. In the later stages of loco poisoning the animals frequently have to catch themselves from falling. Sometimes they do fall indeed and then follows the awkward, hard struggle to again get upon their feet. Most of their motions are "jerky." Even when lifting their hind feet, they bring them up suddenly and rather high, sometimes almost to the belly. As an instance of this inability to control the muscles well, may be cited the almost constant loco from one's hand on this day but would back away, the quivering of his muscles being at the same time distinctly visible. In getting away while cornered along the fence he acted as tho he would climb the latter. He seemed to be able to back up only with the greatest difficulty. At the loco pile he raised and extended forward his left hind leg several times. This was perhaps another symptom of nervousness. He was taken down by the town to a patch of loco but wandered back in the course of an hour to the road leading by the fair grounds. On the 18th the muscles of the animal's legs quivered violently whenever he was touched or driven. He neighed on seeing us. When confronted along the fence, he reared up and fell over backwards. He apparently could not back up at all. He struggled for a couple of seconds before regaining his feet, the hind legs were up a little before the fore legs. He neighed at and came within twenty or thirty feet of one of the other horses on the 19th of September while out on the prairie. On this day the penis of the animal was extruded before urination. A railroad train passed within thirty yards of him but he didn't seem badly frightened, only trotting away slowly for fifteen or twenty feet. When the attendant stopped driving him for a while he turned clear around and went back in the opposite direction for a minute but soon commenced going one way and then another. The skin of his nose quivered while drinking water. This symptom remained from this time on. The faeces being usually dark and somewhat dry were now still darker than ever. On coming to a deep rut he looked down into it before attempting to cross. His weight was found to be 455 pounds on September 20th. On September 21st, while stepping off the scales down to the ground, a distance of 1½ feet, the horse fell into a near-by mud hole and floundered around for a couple of minutes, only stopping to rest, and finally pushed himself out by means of his hind legs, getting up on his fore legs a second afterward. Later he was startled by the sneezing of a bystander. He frequently would leave the loco pile, turning to the right and circling around to it again in a small circle of perhaps six or seven feet in diameter. He jerked his head upward once suddenly but without any apparent cause. On seeing some horses by the corner of the lot in which he was confined, he walked over to where they were and stayed for several minutes. He now walked almost constantly and slowly, sometimes, however, standing perfectly still for several minutes at a time. He caught himself from falling once. Several times he lifted his right hind foot slowly for 6 or 7 inches. He did the same thing again later in the day but this time the action was due probably to the irritation of a sunflower which was touching his foot. On September 22d, he could not be induced to drink out of a pail but would walk right over it. He was scared but slightly at an automobile. On this day for the first time we could put our hands on him without his walking away. He was turned loose during that afternoon to shift for himself and look for loco on the prairie, since the Chase county fair had temporarily deprived him of his quarters. He was not found next day after a thoro search. Perhaps he had wandered into some cornfield. He was found late in the afternoon of September 24th, seven miles from home, by the side of the railroad track. After being driven slowly and with difficulty for half of the distance toward home, he balked and started to go around the driver and back in the opposite direction. He was stopped with a whip and he then whirled around slowly to his right about a dozen times in a circle on the same spot and then stood still with both his fore and hind legs widely apart, the right from the left. When it was attempted to turn him about by whipping his nose, he reared up on his hind legs, striking out quickly with his fore feet, and fell, not attempting to rise at once. This last was unusual, as he always, heretofore, had tried to get up immedireturning with the water the animal was upon its feet. He would not drink out of the water pail when driven up to it but had wanted to stop and drink out of the mud puddles on the road. He walked over one pail and upset it. Another pail of water was slowly placed under his nose and lifted until the water touched his lips, when he drank all right. The penis was

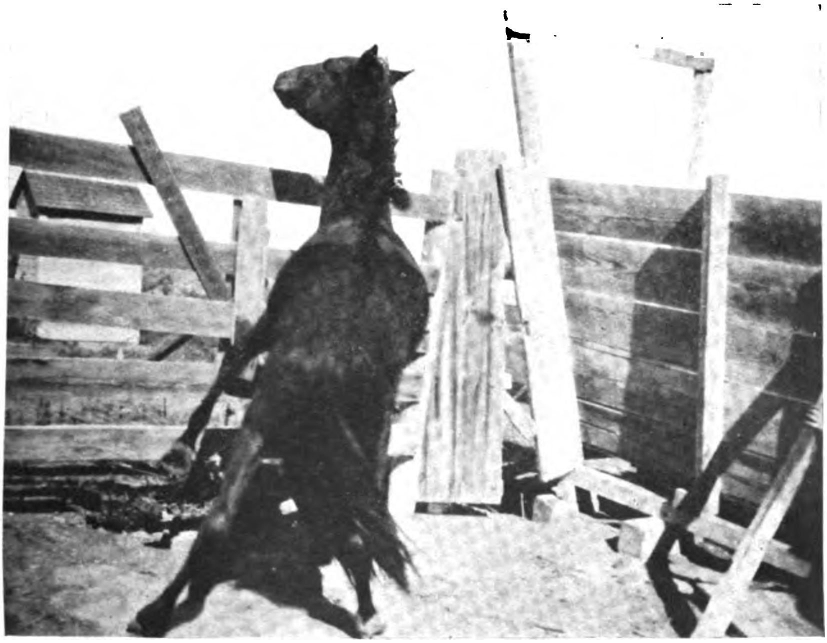


FIG. 3.—Horse No. 2 after being frightened from in front while walking along a fence and near a corner. This shows the poor control over the fore legs.

where the water had spilled. He would not stand still so that the water could be lifted to his lips, so he was driven to a near-by farmhouse where he finally walked up to a tank of water and drank for a long time, after hesitating at every new sight and sound, especially at a mud puddle by the side of this tank. The urine was voided without extruding the penis. On the way home he wanted to stop and eat every loco weed, but a little urging was enough to keep him on a slow walk. He did not turn toward home at the right corner until we compelled him to do so, altho he knew the place well. He would have followed the same road straight ahead if he had been left to himself. On reaching the fair grounds he was placed in the small pasture. That evening at seven o'clock when we called to him he started to walk, but in the wrong direction to find us. In trying to get the animal over to the pile of loco we attempted to turn him by whipping his nose, when he keeled over backwards and fell and did not attempt at once to rise. So the loco weed was placed by his nose and he began eating. He was on his legs, however, in a couple of minutes later.

In the forenoon of September 26th the animal was found to have escaped from the small pasture, and was seen standing still, with head slightly hanging, about two hundred yards south of the pasture fence. He was all scratched up with the barbed wire. He was driven back and shut up in the corral. He had eaten very little loco the night before. On his way back to the corral he took a mouthful of a species of *Aristida* and carried it along in his mouth while scarcely chewing it at all. This grass was full of stickers and was never eaten by the animals. It was of a grayish appearance at this time of year but it is hardly possible that the horse mistook it for loco weed, especially after getting it into his mouth. The horse did not switch his tail much and was fairly covered with flies. Some picked loco was placed in the corral for him. He would take a weed in his mouth, begin chewing it and then walk around the corral chewing at the same time, forgetting to chew after a minute but continuing to walk. The penis was not extruded to urinate. He walked constantly, the fore and hind legs both being rather widely apart, the right from the left. This latter tendency in horses with loco poisoning is noticed only late in the disease. He would stop at the loco pile only long enough to get a mouthful of the weed. Sometimes he would eat the weed, but more often, after chewing for a time while walking, he would stop chewing and later drop the half-chewed mouthful, apparently by accident, or as tho he had forgotten it, never picking up the weed dropped, continuing to walk all the time and returning to the loco pile a minute later for another weed, only to go thru the same performance. He would turn to one side in order to avoid walking into the attendant.

On the afternoon of the 26th he walked along the fence as usual and would frequently stop, stand still for many minutes at a time and shut his eyes. He would, however, open his eyes and move his ears when we made a little noise. On this day he would not keel over backwards as he had done formerly on being slapped over the head with a cap but would move his head or walk straight ahead, never backing up to get away. He would eat loco from one's hand only when cornered along the fence. An excessive or abnormal secretion was running from the animal's eye over onto his cheek. His hair was rougher than ever. On this particular day, as the horse switched his tail against his body you could hear sparks, apparently electrical, the hair of the tail standing out erratically and part of it clinging to the thigh.

On September 27th he drank water only when it was lifted to his lips. When a pail of water was placed on the ground before him he would walk right over it, sometimes striking it by accident with his feet. His fore feet and hind feet were rather widely separated, the right from the left, both while walking and standing. This shows how much control over the limbs was lost. He neighed at seeing us, but it was when we were close to him. His stupor was such that many things failed to attract his attention. There seemed to be nothing inherently wrong with his senses. Weeds and dirt in his mane and scratches on his body showed that he had been down.

On the 28th he would eat from our hands. He would not stand still until a pail of water could be brought to his lips, but after we had finally succeeded in doing this, he drank all right. He paid no attention to the sneezing of a man twenty feet away. The animal was now very much emaciated. His hind legs were placed rather far back and widely apart while he was standing still. A little blood was dripping from his nostrils, giving to his breathing a hissing sound. His nose was swollen slightly. His ears had a decided droop laterally. The straddling of his legs was still worse on this day, both while standing and walking.

On the morning of September 29th the animal was found dead in the corral. He was lying on his left side, the legs being at the standing angle with the body. No rigor mortis was present except a very little in one hind leg, altho the horse was cold by this time. The right eye was half open, the left closed. Emaciation was pronounced. His coat of hair was very rough.

POST-MORTEM EXAMINATION OF HORSE NO. 2.

On post-mortem examination of this animal, the organs of circulation were found to be normal. The respiratory organs were also normal, except for a small amount of amber-colored fluid in the nares and some froth in the trachea. The interior of the turbinated bones was greatly congested. The mouth, pharynx and oesophagus of the alimentary canal were normal. The mucous membrane of the fundic portion of the stomach was of a very dark, red color, and almost black in places. The stomach was empty. A few bots were attached to its wall. Bots were also found in the duodenum for the first eight or ten inches, most of these being attached to the wall. The small intestine was empty thruout, except for a very large amount of yellowish, very tenacious and slightly frothy mucus. Externally on the wall of the great colon, there were several places where the smaller arteries were enlarged. The contents of the great and small colon were appartenly normal. In the first half of the great colon, there was found a large number of small nematodes, each about 1cm. long. The liver was normal. The urinary organs were normal. The bladder contained 4 or 5 ounces of urine. All of the organs mentioned so far were slightly lighter in color than is usual in post-mortem examinations. The brain and spinal cord, however, were both congested. A cherry-red, transparent, organized exudate was found in great abundance in the extra-dural space, i. e., between the dura mater and the periosteum of the vertebrae enclosing the neural canal, all along the spinal cord.

CASE OF HORSE NO. 3.

Horse No. 3 was a sorrel yearling filly which had previously broken a shoulder but had sufficiently recovered so that the accident did not interfere with her gait. She nibbled at loco weed on July 21st and 23d, and again during the forenoon of the 24th when in the large pasture, but not in the late afternoon or on the days following.

LOCO-EATING HISTORY OF HORSE NO. 3.

This filly was a few months younger than Horse No. 2 above decribed. She was much slower and lazier but not so much in the habit of lying down in pasture.

On August 13th there had been picked by mistake a few pounds of *Aragallus lamberti* (stemless loco weed or crazy weed, also known as Colorado loco vetch). This weed was first found four miles east of Imperial. It was deemed advisable to feed this to one of the animals and Horse No. 3 was selected, altho for no special reason. On being corralled at 6 o'clock in the evening she refused to eat any of the *Aragallus lamberti* and did not eat it during the night which followed. On the next day, however, on being left in the corral, she ate 6 pounds of it before 6 o'clock in the evening and was allowed to run at large after that hour. During the next few days she did not nibble loco (*Astragalus mollissimus*). On the morning of August 16th she was driven over to where another animal was eating picked loco. The latter, it was thought, would eat more of it if one of the other horses was there for company. Horse No. 3 started to nibble at the pile of loco but was driven away a couple of times by the biting of the other animal. The same thing also happened in the evening and again on the following day. On August 19th we received some more picked stemless loco weed (*Aragallus lamberti*). Horse No. 3 was accordingly placed in the corral at 3 o'clock in the afternoon and left there. The next day she was fed with this weed and ate, but not readily, 4½ pounds of it, leaving many of the stems untouched. The stems of the weed at that season of the year were particularly tough and dry. On August 21st, before 6 o'clock in the afternoon (after which time she was taken out of the corral and placed in the small pasture), she had eaten fairly readily 3¾ pounds of *Aragallus lamberti* upon being driven back to the pile of weed several times. She returned to the weed pile once after seeing one of the other horses eating picked loco. This much might possibly be due to imitation. On August 22d she was kept in the corral from 12 M. until 7 P. M. and during this time she ate readily 4 pounds of *Aragallus lamberti*. On the 23d she started to eat picked loco at the same pile with horse No. 2, this animal permitting it for the first time, and was corralled at 11 A. M. She was left in the corral for the rest of the day and the night following and ate readily during this time 9 pounds more of *Aragallus lamberti*, eating a plant from the hand of the attend-obtained. On August 25 we offered her, at 6 P. M., 5 pounds of picked *Astragalus mollissimus* (woolly loco weed), which she ate readily. On the morning of August 26 she ate 3½ pounds readily. In the evening she was offered 4 pounds but 2 pounds were found uneaten on the following day. She would now eat loco from our hands for the first time. On the 27th this horse ate readily of picked loco, getting about 1 pound of it. She now also ate growing wooly loco. This was the last picked weed she received except 1 pound on September 6.

The 6 pounds of *Aragallus lamberti* eaten on August 14th was not enough to induce the loco-eating habit. From August 20th to 23d inclusive she was fed 21 pounds of stemless loco above mentioned. On August 25th she ate 5 pounds, on the 26th 5½ pounds, on the 27th 1 pound of *Astragalus mollissimus* (woolly loco weed), receiving 1 pound also on September 6th. Beginning August 20th, this animal received 33½ pounds of picked weed up to the time of her death, September 8th, 19 days later. This is a very short and rapid course for loco poisoning to take and can be explained only on the ground that she ate a large amount of loco in the pasture and possibly to the further fact of her age, her small size, and possibly to her lazy and indolent disposition.

She first showed marked stupidity on August 27th. She would mope along at quite a distance behind the other horses while on the prairie. She would eat scarcely anything but would stand still for many minutes at a time with eyes half closed and with head hanging slightly. At such times she could be aroused by offering her some loco, which she would eat from one's hand. Then of her own accord she would begin grazing on loco and grass, but in a half-minute or so would relapse again into her sleepy attitude. Her other symptoms agreed in general with those exhibited by the horse just described above, so that it will not be necessary to give them in detail. She always, however, showed more laziness and stupidity.

Only a few striking examples of her conduct will be noted. On August 29 the herd boy found her lying on the ground but part way up with her fore legs under her body. He could not get her up even by whipping and by pulling upward on the tail. At 10 A. M. she was up and grazing with the skin mostly gone from the front side of both forefeet at the level of the fetlocks. On September 4, on walking into a few loose wires, she did not look at them closely but walked ahead, lifting her feet very high and showing poor control over them. On September 5th, while getting her onto a platform which was six inches above the ground, it was necessary to lift her fore feet, one at a time, and place them on the raised place, after which she walked onto it all right. On September 7th she was standing at 8 A. M., but down at noon. A man who happened to be present tried to make her get up by whipping her on the withers but failed to do so.

POST-MORTEM EXAMINATION OF HORSE NO. 3.

In only a few particulars did the post-mortem findings of this animal differ from those of Horse No. 2. The superior wall of the abdominal cavity showed much congestion beneath the peritoneum. The stomach did not show any congestion but the mucous membrane lining the cardiac portion of the stomach could be easily stripped off. The stomach and intestines contained a good deal of millet, which, however, the animal had been used to eating occasionally. Four specimens of *Ascaris* were found in the jejunum as well as two tapeworms in the ileum. There was a slight excess of mucus present in the first five of six inches of the jejunum. Externally on the wider, longitudinal, ligamentous band of the caecum were two spots each an inch or more in diameter, where the blood vessels were enlarged and engorged.

CASE OF HORSE NO. 4.

On July 13th, Horse No. 4, a pot-bellied black yearling gelding belonging to Mr. Frank McClain, was added to the experiment. This animal was rather wild and had a noticeable tendency to stumble over rough places in the road. He was a little older and larger than either of the animals just described. His tendency to stumble greatly increased as the experiment proceeded.

LOCO-EATING HISTORY OF HORSE NO. 4.

At 6 P. M. on August 25th he was corralled and offered 4 pounds of picked *Astragalus mollissimus* (woolly loco weed), this species being adhered to in breaking in this animal. He began eating fairly well and the weed was all eaten on the following morning when he ate 4 pounds more. In the afternoon of August 26th at 5:30 he was fed 1½ pounds of loco, which he ate readily. On August 27th all the animals were herded on pasture, and No. 4 ate a good deal of loco in the forenoon but very little in the afternoon. Four pounds of picked loco was eaten by four of the horses in this experiment while in the corral on this day. The loco eating habit had now been formed by No. 4, which received practically no more picked loco weed until October 3d except 14 pounds on September 6th and 7th. On October 3d we began feeding large amounts, since it seemed evident that another month of grazing without additional feeding of loco would not kill the animal. From October 3d to 14th inclusive, on which latter date he died, he ate 196 pounds of picked loco, varying from 1 pound to 45 pounds per day, receiving an average of nearly 18 pounds per day during this time.

SYMPTOMS OF HORSE NO. 4.

On September 23d, on escaping from pasture at the fair grounds, he started on a swift walk down the usual road toward the prairie where the loco grew, but stopped and came back on hearing the neighing of one of the other horses, which he answered. From this time on until the time of his death, on

October 14, he showed practically all of the symptoms of Horse No. 2, with some more pronounced symptoms which will be specially mentioned.

He balked occasionally and could then not be started by whipping. He stayed very close to another one of the horses, especially on one occasion after having been corralled by himself all day, when he pressed so closely against the side of this other animal as if afraid of losing her, that she laid back her ears at him. He lifted his feet higher than any of the other horses in crossing the rails of the railroad track. He stumbled more frequently, and fell as a result of this oftener, than any of the other horses. In the forenoon of October 4th he started down the road along the railroad track and was hard to turn back until he stumbled and fell at the edge of a ditch, when he made one trial to get up, then did not try again for a couple of minutes. After this rest he succeeded all right. On getting up he started straight toward home. On running into some wires which lay on the ground he balked, but after some urging he went ahead slowly, lifting his feet 12 inches or more in order to step over them but not looking down at them at all. When he came to where the fence had been previously, nothing being now left but the posts, he cautiously pressed forward after turning to one side for an instant as tho fearing that the fence wires were still there. On getting out into the open he fairly ran down to the large pasture where Horse No. 1 was, since he had been alone in the corral all day. When the two met they both neighed loudly and long. He pressed close to the side of this animal as space along the spinal cord was of a buff color in the sacral, lumbar and last half of the dorsal region, becoming cherry-red in the first half of the dorsal and even brighter, almost a dark red, in the cervical region. The dura mater in the cervical region was distended by a serous fluid. The stomach was enormously distented by loco weed, the organ with its contents weighing about 28½ pounds. The mucous membrane of the cardiac portion was easily stripped off, while that in the fundic portion was intensely congested, amounting to an inflammation. The pyloric portion contained an excessive amount of mucus. This excess mucus continued through the duodenum, jejunum and the first part of the ileum, the last portion of this last organ containing much loco weed, which was not found in any amount in the rest of the small intestines. In the first jart of the ileum there were present 31 cestodes (dead when found). These were unusually long specimens, one of them measuring 30 cm. Three specimens of *Ascaris* (dead when found) were present near the junction of the jejunum with the ileum.

Externally and irregularly over the small intestines and great colon some of the smaller arteries were somewhat enlarged and congested in irregular patches, each from two to four square inches in area.

The great colon contained practically no nematodes and was full of loco weed, appearing like normal colon contents. The small colon was full of loco weed, with a very slight excess of mucus. The trachea contained no froth. The pericardial fluid was slightly increased in amount and had a slight reddish tinge. The other organs than those mentioned were all normal or slightly pale in appearance.

CASE OF HORSE NO. 5.

Horse No. 5, a two-year-old bay gelding belonging to Mr. O. P. Shallenberger, was also added to the experiment at this time, but was returned to the owner on request September 16th without having developed the loco-eating habit, and will not again be mentioned in this article.

CASE OF HORSE NO. 6.

Horse No. 6, an iron-gray yearling gelding belonging to Mr. Below, was added to the experiment on July 16th. This animal was crippled with a broken humerus on the left side which had united badly and caused severe lameness. On the right side of his neck, below the mane, was a small tumor, not covered by the skin. A second tumor was present between the forehead and the nose, just below the level of the eye. This animal nibbled at loco weed on July 23d only, when the grass in the small pasture was practically gone. He was allowed to run at large after this date, since his crippled condition made it appear inadvisable to take him over to the large pasture and back again every day. On August 6th we put him in the corral and offered him some picked loco weed, which he refused to eat. We left him in the corral that night. During the next day and night following he ate fairly readily 13½ pounds of picked loco weed. On August 8th and the night following he ate 8½ pounds, leaving about 1 pound uneaten. On the 9th he was in the corral part of the day and the rest of the time in the small pasture, now containing little or no grass. On August 10th he was turned out and allowed to run at large, when he ate readily 4½ pounds of picked loco weed placed in front of him. The next day he refused to eat picked loco placed before him, so he was again put in the small pasture, where he began eating it at once, only one pound out of the eight given him being left on the morning following. On August 12th he finished 8 pounds in the corral and was then turned out to run at large in the evening. On the day following while at large he ate 4 pounds of picked loco readily. On August 14th he was missed in the afternoon and found in the evening of the next day as he was coming out of a near-by cornfield. He was offered loco, which he would not eat, and was

The noise caused by the churning about of the intestinal contents was distinctly heard. But little gas was present, not enough to produce noticeable distension of the abdomen. The corral gate was opened toward evening, when he was given water from a pail, but he did not, perhaps could not, walk out altho the gate remained open all night. On the day following he drank some water in the morning but could not in the evening, dying some time that night.

Autopsy of this animal on August 18th revealed mostly grass in the first half and apparently corn leaves in the last half of the great colon, while an excess of mucus was found along the small colon. Death was due, in all probability, to colic induced by an unusually large amount of corn leaves, to which the animal was unaccustomed.

SUMMARY.

LOCO-EATING HISTORY.

Hunger will lead many horses to eat loco weed when the grass is short, especially in the early spring or in the late fall, or even in wet seasons when the grass is not short, probably because the weed is then more succulent. A small grain ration when the grass is short will usually be sufficient to keep the animals from forming the loco-eating habit. After a horse has eaten loco for a time, this habit becomes permanent in most cases.

It was permanently formed in Horse No. 2 after 118 pounds of picked woolly loco weed (*Astragalus mollissimus*) had been eaten and probably long before this time. This animal lived 62 days after the picked loco was first fed and consumed a total of 322 pounds of this besides that eaten in pasture and on the prairie.

Six pounds of picked *Aragallus lamberti* (stemless loco weed or crazy weed, also known as Colorado loco vetch) on August 14th was not sufficient to induce the loco habit in Horse No. 3. We began to feed her with this weed again on the 20th. The loco-eating habit was this time permanently induced in the sorrel colt after 21½ pounds of picked *Aragallus lamberti* and 10½ pounds of picked woolly loco weed (*Astragalus mollissimus*) had been eaten. The animal died 19 days after the first of this weed had been fed, if we except the 6 pounds of *Aragallus lamberti* on August 14th. After the loco-eating habit had been induced in this animal, one pound only of picked woolly loco weed was fed, practically all being eaten while grazing on the prairie.

The loco-eating habit was permanently induced in Horse No. 4 by 5 pounds of *Astragalus mollissimus* fed on each of two successive days. The total amount of picked woolly loco eaten by this animal was 221½ pounds. The horse died 50 days after the first of this was fed.

SYMPTOMS.

The first indication pointing to loco weed poisoning is usually the loss of flesh. The animal becomes very poor. The characteristic "stiff knee" gait also soon becomes noticeable in the forelegs. The symptom of most value, however, in diagnosing this condition is the loco-eating habit. The horse will eat the weed at almost every opportunity. Distinct irregular swellings more or less bilaterally symmetrical appear early, on the cheeks and side of the lower jaw as well as on the place behind the lower lip. These swellings persist for a day or two and often recur for several times at irregular intervals but with less severity. Distinct enlargement of the lymphatic glands in the intermaxillary space of the lower jow just in front of the throat is early to be seen. This condition persists. The quivering of the muscles, especially of the limbs, together with inaccurate and jerky movements of these, are best noticed when the horse is excited.

things is probably unimpaired. They will usually return after a day or two when they have wandered several miles from home.

They show very plainly their love of company and their intense dislike of being alone. They exhibit signs of fright where we would hardly expect them and on the other hand they fail to show these in many cases where they could be reasonably looked for. In general they are more often and more severely frightened than would be the case in a normal animal. We cannot agree with the opinion formerly held by some that a locoed animal becomes frightened at imaginary objects analogously with "ghosts" or "snakes" in the human subject. A locoed horse becomes very tame as the condition progresses. Periods of

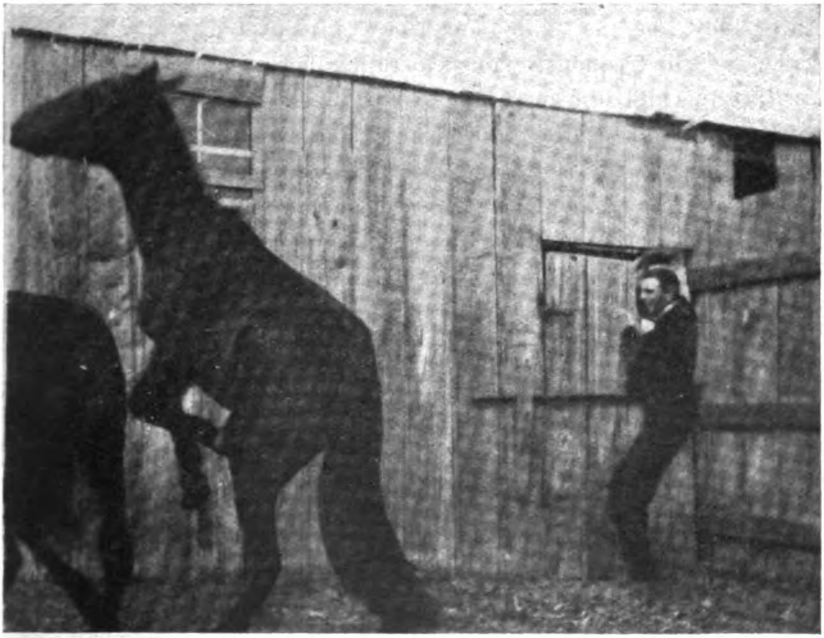


FIG. 4.—A locoed horse on being frightened while in a corner and trying to get away. This shows poor control over the fore legs and inability to "back up."

stupor lasting for many minutes or even hours, when the animal stands perfectly still with eyes half closed and head hanging, are interrupted temporarily by aimless walking about or by other nervous, "uneasy" actions. The irritable disposition is best displayed when the animal is with other horses. The stubborness is most in evidence when he is led or driven to some place where he does not want to go. A locoed horse is proverbially slow, or, as it is sometimes interpreted, "lazy." Even then he will frequently run into things before noticing them, but will soon right himself when he is thus aroused from his dreamy stupor. When feeding in a certain spot he will frequently leave it, turning to the right and describing a small circle to return again to the same place. He seems to mistake all small gray objects for loco weeds until a closer inspection shows him his mistake. In his dream-like stupidity also he forgets to fight the flies. He will blindly and even stubbornly follow a fence, a road, or another horse, or go ahead in a straight line for a long distance without any apparent end in view.

A group of "locoes" in a corral will frequently form in single file and follow the fence from corner to corner around the enclosure many times.

A locoed horse exhibits many symptoms showing poor muscular control. His walking is slow and labored, his head at the same time moving up and down to an exaggerated distance. While standing still, his head hangs lower than is normal. He raises his feet slowly and very high in stepping over obstacles in his way. Flexion seems to be more difficult than extension. There is an increasing tendency to stumble. The animal when lying down gets up like a cow on the hind legs first. The hind legs are not so much affected in the horse. A slight tendency for the feet to be placed too widely apart, especially the hind feet, the right from the left is noticeable in the last stage of the to make him do this he will rear up and fall over backwards. Later in the disease, instead of rearing up this way he will simply run straight ahead when anyone tries to make him back up by whipping his nose.

In some cases the lips will quiver excessively while the horse is drinking. The eye appears somewhat glassy from an excess of secretions. The urine in late stages of the condition is voided without extrusion of the penis, which is sometimes extruded a minute later.

POST-MORTEM EXAMINATIONS.

Some entirely new findings of the Department of Agriculture in the experiment at Hugo, Colorado, were confirmed by us, concerning the pathology of loco weed poisoning.

All of the horses when found dead were lying on the left side and the legs were at right angles with the body as they are when the animal is standing. The abdomen was not so soon distended by gas as is usual in the horse. There was no rigor mortis present save a very little in one hind leg. The hair was very rough and the animal in every case was very greatly emaciated. A small amount of amber-colored fluid was coming from the nostrils. This was a sero-sanguinous exudate of the mucous membrane of the nasal chambers, particularly that covering the turbinated bones. The eye next to the ground was closed, the other one being half open.

The organs of circulation were normal. The heart was normal in size and weight and the valves were all competent. A slight increase of the pericardial fluid could be noted. The organs of respiration were also normal except for congestion of the turbinated bones, with the exudate mentioned in the nasal chambers, and perhaps a slight excess of pleural fluid. The general condition of the abdominal cavity was good, the organs appearing normal or slightly pale. Here and there, along the intestines externally, or on the parietal peritoneum, might be seen an occasional small, slightly congested patch. The alimentary canal was normal as far as the stomach, where the lining coat of the cardiac portion of the mucous membrane could be easily stripped off, the fundic or second portion was very badly congested amounting to an inflammatory process, and the pyloric or third portion of the organ was covered with a very great excess of mucus coming no doubt from the congestion of the fundus. This excess of mucus, altho not so great, was found all along the remainder of the alimentary tract, as were also many bots which had come from the stomach wall. Horse No. 3 did not show the congestion but the lining of the cardiac portion could be easily stripped off. The disease in this animal ran an acute course, which perhaps explains this. Bots were present in the stomach but many of them were loosened from the wall and many more were found loose in the intestinal contents. The stomach contents were very small in amount, except in the case of Horse No. 4, where the organ was enormously distended by loco weed, the stomach with its contents weighing 28½ pounds. The contents looked normal save for the slight excess of mucus.

The intestinal contents appeared normal save for some excess mucus. In the case of Horse No. 2 the mucus was present in the small intestines in a very excessive amount, there being few or no other intestinal contents. In character this mucus was tenacious, yellowish-white and slightly frothy. The slight excess of mucus persisted thruout the large and small colons and the rectum, but the contents were otherwise normal.

The spleen in one case was normal, in another it had a greenish cast, and in still another, Horse No. 3, it was bright red in its posterior third. bluish-black in its middle, the rest being dark blue. The kidneys were normal or slightly pale, as were also the other abdominal organs.

The greatest change of all was noticed in the nervous system.

jelly-like exudate which was organized, having a cherry-red color due to the numerous tiny blood vessels running thru it in all directions. This exudate extended to the foramen magnum and was not adherent to either periosteum or dura but clung to the spinal nerves at their origin, since it ran thru and filled the opening between the anterior and posterior nerve roots in each case and was thus held in place by these. It was in greatest amount at the cervical region. In this region the exudate was a very deep red, becoming much lighter, almost a pink, in the dorsal region, while in the lumbar region it was scarcely more than a buff color or an orange-pink.

THE UNIVERSITY OF NEBRASKA

TWENTY-SECOND ANNUAL REPORT

OF THE

Agricultural Experiment Statio

OF

NEBRASKA

Presented to the Governor February 1, 1909

LINCOLN, NEBRASKA
U. S. A.

THE UNIVERSITY OF NEBRASKA

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FEB. 15. 1869.

PRESENTED TO THE GOVERNOR FEBRUARY 1, 1909

LINCOLN, NEBRASKA
U. S. A.

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LETTER OF TRANSMITTAL

THE UNIVERSITY OF NEBRASKA
AGRICULTURAL EXPERIMENT STATION

To His Excellency, Ashton C. Shallenberger, Governor of Nebraska:

SIR—In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Twenty-second Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
Director.

February 1, 1909.

GOVERNOR'S CERTIFICATE

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT,
LINCOLN, FEBRUARY 1, 1909.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR—I hereby acknowledge receipt of the Twenty-second Annual Report of the Nebraska Agricultural Experiment Station.

ASHTON C. SHALLENBERGER,
Governor.

THE OFFICIAL ROSTER OF THE STATION

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THE WORKING STAFF

E. Mead Wilcox, Ph. D., *Agricultural Botany*
F. J. Alway, Ph. D., *Agricultural Chemistry*
H. R. Smith, B. Sc., *Animal Husbandry*
A. T. Peters, D. V. M., *Animal Pathology*
A. L. Haecker, B. Sc. A., *Dairy Husbandry*
Lawrence Bruner, B. Sc., *Entomology*
E. G. Montgomery, B. Sc., *Field Crops*
Frank J. Phillips, M. F., *Forestry*
Erwin H. Barbour, Ph. D., *Geology*
G. R. Chatburn, A. M., *Highway Engineering*
R. A. Emerson, B. Sc., *Horticulture*
O. V. P. Stout, C. E., *Irrigation*
G. A. Loveland, B. Sc., *Meteorology*
Alvin Keyser, A. M., *Soils*
W. P. Snyder, M. S., *Superintendent Experimental Substation, North Platte*
C. W. Pugsley, B. Sc., *Associate in Animal Husbandry*
J. H. Gain, M. D. C., *Associate in Animal Pathology*
L. B. Sturdevant, A. M., *Assistant in Animal Pathology*
Venus W. Pool, A. M., *Assistant in Agricultural Botany*
R. S. Trumbull, A. M., *Assistant in Agricultural Chemistry*
E. M. Little, B. Sc., *Assistant in Dairy Husbandry*
M. H. Swenk, A. M., *Assistant in Entomology*
Robert F. Howard, B. Sc. in Agr., *Assistant in Horticulture*
P. B. Barker, A. B., *Assistant in Soils*
W. W. Burr, B. Sc., *Assistant in Soils and Crops, North Platte*
S. W. Perin, *Farm Superintendent*

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TWENTY-SECOND ANNUAL REPORT

EXPERIMENTAL WORK

The work of the Nebraska Agricultural Experiment Station for the current year has been as follows:

The lines of investigation in the Experiment Station are of two classes: First, those which are technical and scientific in their character, endeavoring to discover scientific principles which may have a bearing on practical farm problems; second, the adaptation of scientific principles already worked out to the practical needs of the farmer.

The investigations carried on under the Adams Act are, by the limitations of Congress, confined to original investigation along strictly scientific lines, in an effort to accumulate information of a scientific character and to work out the application of this knowledge to practical agricultural questions. Of necessity, on account of limited appropriations, the number of problems which can be studied under the Adams Act are limited, and have been confined at our Station to a study of the relation of food to the deposit of mineral matter affecting the strength of bones in pigs; to the method of determining humus in soils, the composition of humus, and the effect of tillage and crop production on soil fertility. These investigations have also included: a study of heredity and the effect of crossing on heredity in plants; a study of plant diseases, especially those which affect farm and orchard crops; a study of the relation of leaf area to water loss and growth in the corn plant, and a laboratory study of tuberculosis in hogs to determine if possible how to detect tuberculosis in the living hog; also to determine the methods of transmission of the disease from cattle to hogs.

The other funds of the Experiment Station, such as the Hatch fund appropriated by the Federal Government and State appropriations, are available for less technical lines of investigation which may have the most immediate and beneficial influence on the general farm practice of the State. In this connection it may be said that the work of the Experiment Station at the central plant has entirely outgrown the appropriations available for experimental work, so that no new lines of investigation have been undertaken in the last two years except those which have been inaugurated at the North Platte Station. The lines of investigation now in progress would be much facilitated and many new lines of work might be undertaken if the State were to make a specific appropriation from the general fund to promote the work of the central experimental plant.

A very thoro review of the work in progress at the central station was made in the Twenty-first Annual Report and it is unnecessary to repeat here the results recently published in this Report, which is still available for distribution.

TUBERCULOSIS.—Progress has been made in the study of tuberculosis in hogs, for which a special appropriation of $1,000 was made by the last Legislature, this sum being supplemented by Federal funds and by assistance from private sources. This work has been done largely at the packing houses in South Omaha and in the tracing of infected lots which were condemned in the packing house to the farms on which they were fed and endeavoring to determine the cause of infection on individual farms. The cooperation of the Federal Inspectors in the packing house has been secured, so that they have reported to our office the records of animals condemned at the South Omaha slaughterhouses where Federal inspection is maintained. The cooperation of the packing house was also secured in reporting the owners or the localities from which condemned animals were received. A representative of the Station visited these farms to ascertain the source of infection, whether thru the milk or thru the feces or thru diseased attendants. Representatives of the Station visited 280 farms on which either hogs or cattle had been reported affected as indicated by condemnations on the South Omaha markets. As a result, 63 herds tary on the part of the owners of cattle, indicating their willingness to cooperate and their desire to have their herds clean and free from disease.

Since September, the Bureau of Animal Industry of the United States Department of Agriculture at Washington has detailed two veterinarians to assist the Station in testing herds thruout the State. These veterinarians are supplied by the Government free of charge. The only provision required by the Government is that the owners who have their herds tested consent to clean up their premises and destroy the animals that react.

SWAMP FEVER.—The Station has made careful investigations to ascertain the extent of the prevalence of swamp fever in the State. This disease has been somewhat prevalent in the region of Holt County, and many other counties in the northwestern part of the State have reported cases as swamp fever which upon investigation have proved to result from other causes. The Department has made many post-mortem examinations and also investigated the prevalence of a parasite in the horses which died from swamp fever to ascertain if this worm has any connection with causing the disease. Every possible factor which might account for the symptoms produced in this disease has been studied without making much progress which would lead to its successful treatment. Various medicines are being tried on animals that are affected with the disease, but up to the present time 90 per cent of the animals affected have died and those that recovered have not been very useful afterwards.

HOG CHOLERA.—Experiments have been made within the last year with the Government method of hyperimmunizing hogs against cholera. These experiments have been fairly successful in proving that hogs may be immunized by the simultaneous injection of virulent blood and of serum from blood drawn from hogs which have previously been hyperimmunized against cholera. In the experiments on the Station herd the loss of hogs by this method was about 10 per cent. Many trials by the Government have been more successful, but the results of investigations have not been uniform. Investigations are under way to see if this method can be perfected so that the cost of treatment may be reduced and the method made practical for commercial purposes.

CATTLE FEEDING.—Cattle feeding experiments have been conducted with individual steers to test the comparative value of four so-called protein supplements, namely, wheat bran, linseed-meal, new process cottonseed cake, and alfalfa hay, each fed with shelled corn and shredded corn-stover. The largest average daily gains (2.8 pounds per day) were made on the ration containing cottonseed-cake as a supplementary food, followed by alfalfa, bran, and linseed-meal, in the order named. The largest profits were made on the ration containing alfalfa followed by those containing cottonseed-cake, wheat bran, and linseed-meal, in the order named. In two former tests linseed-meal proved more economical than either bran or cottonseed-meal. In the test here reported, new process cottonseed-meal was used for the first time and gave better results than have ever been secured by us with old process cottonseed-meal. Cottonseed-meal and linseed-meal each formed 10 per cent of the full grain ration fed, bran 25 per cent, and alfalfa made up half of the roughness, the grain in that lot consisting of shelled corn alone.

In comparing a full feed of corn, averaging approximately 20 pounds per day, for a period of four months with an average daily ration of 17 pounds and another of 12 pounds, alfalfa and corn-stover forming the roughage in all lots, the profits were almost identical on the two larger rations, corn costing 52 cents per bushel and alfalfa $7 per ton. The profits on the smallest grain ration were lower than on the other two named.

PIG FEEDING.—In fattening pigs with foods supplementary to corn, reported in Bulletin 107, the hogs made more rapid gains where supplementary foods were used and reached heavier weights in a given length of time. The cheapest gains were made on the lot receiving no supplementary food after they were removed from pasture, altho other experiments indicate that 5 per cent tankage has been more profitable than the feeding of corn without some supplementary food.

The effect of food on the breaking strength of bones, reported in Part II of Bulletin 107, indicates that the addition of ground bone, tankage, or skim-milk to a corn ration produces a marked effect on the quality and the breaking strength of the bones when fed to growing pigs, as shown by the following table.

Average breaking strength of bones per 100 *pounds live weight of hogs at time of slaughter.*

Lot.	Ration.	Femur.	Tibia.	Humerus.	Radius and ulna.	All bones
1	Corn....................	276	252	434	341	325
2	Corn and shorts..........	343	309	555	376	396
3	Corn and skim-milk.....	462	360	685	529	509
4	Corn and tankage.......	559	409	740	611	580
5	Corn and ground bone...	646	465	898	715	681

A further investigation also shows that the thickness of the bone walls increased and that the cell walls were thicker and contained more mineral matter where a supplementary food was added to the ration than where corn alone was fed. When bonemeal was fed, the thickness of the bone walls increased about 50 per cent, the specific gravity of the bones was greatly increased and the bone was harder and denser than where no supplementary food was used.

Milking Machines.—During the past year extensive experiments in the use of the milking machine have been in progress, as reported in Bulletin 108. These investigations show that heifers in their first lactation apparently give better results by machine milking than do aged cows that have been accustomed to hand milking; that some cows are not adapted to machine milking; that alternate hand and machine methods of milking have been detrimental to the milk flow; that manipulation of the udder is absolutely necessary in some instances before the milk can be drawn by the machine; that one milker may operate two machines and do satisfactory work; two milkers operating four machines can do the work of three men milking by hand; one operator with two machines can milk between ten and eleven cows per hour. It was found necessary to thoroly wash and boil the milking machine parts after each usage in order to produce milk which is as sanitary as that resulting from careful methods of hand milking. The man operating a milker must thoroly understand the care and management of dairy stock and be persistent in the attention to details in order to get good results. From these studies it would appear that the milking machine is fitted for large herds rather than small ones, and we believe it would be impractical to install machine milking where fewer than 30 cows are milked.

Investigations have been in progress in an effort to acclimatize and select improved strains of wheat, corn, oats, barley, and alfalfa. Among the varieties of selected wheats originated in the nursery which have been tested in the field for two years, one or two superior varieties have been developed in which the average yield per acre has been 4 bushels more than the unselected wheat.

Rolling winter wheat in the spring has given an average increase of 5 bushels per acre for the past 5 years. Harrowing winter wheat in spring has given an increase in dry years and a decrease in years of more than normal rainfall. Harrowing oats has given an increase of 4.8 bushels per acre as an average for a period of seven years.

CORN.—A comparison of several strains of selected corn with the old unselected seed has given an increase of 9 bushels per acre for the selected strains. Where 200 ears of corn were tested separately for yield, only a part of the ear being used, the remnant of the 10 highest yielding ears planted the following year produced 70 bushels per acre and the 10 lowest yielding ears 49.7 bushels per acre, or an average of 20.3 bushels per acre more for the 10 highest than for the 10 lowest yielding ears. Where 200 ears were tested in individual rows, in the same manner, the remnants from the 100 highest yielding ears gave an increase of 6 bushels per acre over the remnants of the 100 poorest yielding ears. Where several selected strains of corn were compared with the unselected seed from which these strains were derived, they gave an increased yield of 9 bushels per acre for the selected strains. These results indicate that we cannot reach the highest degree of improvement in seed corn without testing individual ears of corn to determine which of the ears selected have the highest prepotency or quality to transmit a high yielding character. Since it requires only 10 or 11 ears to plant an acre of corn, and since the high yielding strains when once isolated by planting in the ear-to-row method will continue to show this high yielding character to a considerable degree, it is practical for the grower of improved seed corn and even for the grower of corn on a large area to practice this method in the selection of seed for his field planting.

This is done by selecting about one hundred of the best ears and planting each in a separate row. Before the sprouting ears have been pollenized, one should detassel all stalks which do not show strong ears. There are saved as many as are needed of the best ears from the best rows, to plant in the breeding plat next year. All the good ears from the best yielding rows are used for planting the main field.

SMALL GRAIN.—Experiments are in progress with winter oats, winter barley, and winter emmer in an effort to develop winter varieties which are hardy for considerable areas of the State.

An investigation of the fertility of the soil and the effect of crop production on the loess soils of the State indicates that to maintain the supply of organic matter erosion by water and by wind must be prevented so far as possible. The burning of stalks and straw should be avoided, and all barnyard manure should be returned to the land. Even if these precautions are observed, there will be a steady decline in the cultivated fields unless legumes be grown or the produce of other fields be fed and the manure applied. By growing clover or alfalfa the nitrogen, humus, and unhumified organic matter may be increased at the same time that profitable crop production is maintained.

An effort has been made in a limited way to test the effect of commercial fertilizers in Lancaster, Johnson, Pawnee, and Jefferson Counties. This work is done largely at the expense of the cooperators and indicates as a rule that the addition of nitrogen in the form of commercial fertilizers always increases the production of the land and increases the profit of the crop where a grain crop is grown upon land that has been some years in crop without much attention being paid to maintaining the fertility of the land. These experiments together with those above mentioned indicate that the nitrogen necessary to produce a profitable crop and maintain soil fertility may be supplied by the use of clover and alfalfa used in a rotation with grain crops. There can be little question as to the advantage of placing all cultivated land in the older sections of the State under a rotation which shall include grass, clover, or alfalfa on the land for two or three years in a 7-year rotation.

Some statistics recently gathered on this subject indicate that where land which has been for some years in crop is laid down to grass for two or three years, the fertility of the land is greatly increased. This is indicated by an increase of about one-third in the yield of corn following grass as compared with corn grown on land for some years in grain crops. With these evidences of increase in production and in the profit from operating land under a system of crop rotation, it can hardly be possible that intelligent farmers will continue a single-crop system in this state. A suitable rotation should include—the growing of both corn and small grains, interspersed with leguminous crops, such as clover or alfalfa, or of suitable pasture crops.

COOPERATIVE EXPERIMENTS

Cooperative experiments are in progress with farmers in the State in testing varieties of corn adapted to different regions; in extending the area of winter wheat; in introducing winter barley and winter oats; in the testing of commercial fertilizers to determine the effect of the application of a nitrogen fertilizer, a potassium fertilizer, or a phosphorus fertilizer, or a combination of these three on crop production.

Experiments in cooperation with the Federal Department of Agriculture are in progress, to improve the quality and production of hard winter wheats; to introduce new crops into the State; to control apple scab and codling-moth by spraying; to study the effect of tillage and of crop rotations on crop production; to study the alkali-resistant crops; to make a general plant disease survey of the State; and to determine the extent and kind of adulterants and impurities of seeds distributed by seedsmen.

THE NORTH PLATTE STATION

WINTER WHEAT ON SUMMER TILLED LAND.—Systematic experiments carried on to test the effect of summer tillage in the growth of winter wheat give almost phenomenal results. The yields on the North Platte Station farm for the last three years have been: in 1906, 42 bushels per acre; in 1907, 59 bushels per acre; in 1908, from 50 to 67 bushels per acre on considerable areas grown under field conditions. Wheat on adjoining fields not summer tilled produced, in the same years, from 20 to 24 bushels per acre, with a yield of 41 bushels in 1906, a year with 9.13 inches above the normal rainfall. The two leading varieties of winter wheat have been the Kharkov introduced thru the United States Department of Agriculture and the Turkey Red, a standard variety long in use in this State.

SPRING WHEAT.—The tests of spring wheat at the North Platte Station have indicated a decided advantage of the durum wheats over the local variety of spring wheat which is in common use in western Nebraska. The average yield of a leading variety of durum wheat for the past three years on land which has grown a crop the previous year has been 28 bushels per acre, where the average of the local variety has been but 17 bushels. Some farmers have been inclined to discriminate against the growing of durum wheats because they did not sell at as high a price on the market as the winter and local spring wheats. The Station has proven by experiments that durum wheats are worth at least as much as corn, pound for pound, in feeding hogs, and that at current prices for corn durum wheat is a profitable crop to use in feeding live stock.

BARLEY.—Investigations in the growing of barley have shown that the local variety of barley is superior to any of the introduced varieties and that barley is a more profitable crop than emmer or speltz to grow for feeding purposes, since it gives a higher yield per acre and has a higher feeding value.

OATS.—Tests of varieties of oats indicate that the Kherson oat is still the leading variety, altho some of the introduced sorts, if sufficiently early, may be reliable and profitable. The work of the Station has shown that an early oat has a great advantage over a late oat thruout all of western Nebraska, since it is likely to ripen under more favorable weather conditions than exist later in the season.

Among the annual forage crops, sorghum, or cane, has given the most satisfactory results. Kafir corn and milo maize have been used to a limited extent but have not yet proven equal to cane for forage purposes.

Alfalfa has proven itself to be greatly superior to any other perennial forage crop for land where alfalfa may be grown, as can be done on almost all of the valley lands of western Nebraska and on many of the table-lands where no alfalfa is grown at the present time. There is hardly a section in the western part of the State where some small fields of alfalfa may not be found growing under natural farm conditions and producing much more forage than could be grown under the same conditions with any other crop than cane or some quick-growing annual crop. The yields at the North Platte Station indicate that on bench lands which are from 20 to 30 feet above water 4 tons of alfalfa per acre may be considered a normal crop. The value of this forage in the wintering of cattle, horses, and hogs has been shown to be superior to prairie hay or to cane in stock feeding, as reported in Bulletin 105 (Substation Bulletin No. 3).

Experiments in dry-land farming would indicate that summer tillage should be used upon limited areas of land for the growing of winter wheat. It has been proven that a period of summer tillage prior to sowing winter wheat stores up a sufficient amount of moisture in the land to practically insure the crop against drought and that a reasonable crop of winter wheat could be grown with a minimum rainfall where, without summer tillage, all crops would probably fail. Summer tillage is not recommended for crops other than winter wheat, on account of the possibility that the land may drift in winter, altho there are doubtless conditions under which spring sown crops can be grown with profit on summer tilled land.

Experiments in tree planting and in orchard growing have been in progress at the Substation for the past two years and show an excellent growth where good stock and good cultivation have been given. Cottonwood trees more than 10 feet high have been grown in two seasons from selected one-year-old stock planted in 1907. The results of this work will be reported in Bulletin 109.

GROWING HOGS.—Extensive investigations are in progress to determine the most profitable method of producing pork where using prairie hay, sorghum hay, alfalfa hay, and a mixture of alfalfa with each of the other kinds of forage named. The first report of this work is published in Bulletin 105 and the second experiment is in progress with yearling steers at the present time which were purchased and fed as calves upon the rations named and will be continued thru the present and a succeeding winter to determine the cumulative effect of these rations and the cost of wintering cattle under these different methods. The results of the first experiment indicate that alfalfa hay or alfalfa mixed with an equal quantity of prairie hay or of cane gave much more satisfactory results than where prairie hay or sorghum hay is fed alone. Where alfalfa formed the whole or a part of the ration, the animals gained thruout the winter. Where no alfalfa was used in the ration, the animals always lost weight and went upon grass in the spring lighter than they went into the yards in the fall.

An experiment is in progress to determine the effect of growing colts upon alfalfa hay and alfalfa pasture in comparison with alfalfa hay and prairie pasture and also in comparison with prairie hay and prairie pasture. These experiments were started in November, 1907, and at the present time indicate a marked advantage where alfalfa forms a part of the ration.

THE STATION STAFF

Within the past year the following changes in the Station staff have taken place:

Dr. F. D. Heald resigned as Agricultural Botanist, and Dr. E. Mead Wilcox was employed to fill the vacancy, beginning September 1, 1908.

Mr. A. F. Magdanz, Jr., A. B., resigned as Assistant in Animal Husbandry. Mr. C. W. Pugsley, B. Sc., was employed to fill this position, beginning September 1, 1908.

Miss Stella A. Hartzell, A. M., resigned as Assistant in Agricultural Chemistry, and Mr. R. S. Trumbull, A. M., was employed to fill this position, beginning July 1, 1908.

Mr. F. E. Denny, A. B., resigned as Assistant in Horticulture May 1, 1908. Mr. Robert F. Howard, B. S. in Agriculture, was appointed to fill this position beginning December 1, 1908.

Mr. Martin Nelson, M. S., resigned as Assistant in Field Crops October 1, 1908.

Mr. Myron H. Swenk, A. M., has been employed as Assistant in Entomology; Miss Venus W. Pool, A. M., Assistant in Agricultural Botany; Mr. P. B. Parker, A. B., Assistant in Soils; and Mr. W. W. Burr, B. Sc., Assistant in Soils and Crops at the Substation, North Platte.

IMPROVEMENTS

Since the last Report, a veterinary laboratory has been erected for the Department of Animal Pathology, at a cost of $12,500. This was made necessary by the destruction of the old Animal House, which was located in the middle of the main quadrangle of the campus and was no longer suitable for the work of the Department. This building had to be torn down in the development of the general scheme of improvement which is being carried on. About $7,500 has been expended in the improvement of the farm campus; otherwise no expenditures for improvements have been made since the last Annual Report.

FARMERS' INSTITUTES

Several members of the Experiment Station staff have assisted in Farmers' Institutes during the year. One hundred and seventy-five Institutes were held during the year closing June 30, 1908, and 150 Institutes are scheduled for the current year. The Farmers' Institute Department desires, in addition to carrying on the present Institute work, to establish a number of short schools of agriculture which shall continue for one week at suitable points in the State, giving systematic instruction in two or three lines of work at each Institute, which are included in the following list, namely: rotation of crops and the maintenance of soil fertility; principles of crop production; selection and growing of seed corn; buttermaking and the development of the dairy industry; the breeding, selection, and judging of beef cattle; the breeding, selection, and judging of swine; the breeding, selection, and judging of horses; the care and management of poultry; the care and management of orchards; lectures and demonstrations in domestic science, including: the relation of food to the body; the composition and cooking of meats;

the preservation of fruits; canning jellies, etc.; salads and desserts; kitchen economy, including the use of the fireless cooker; with demonstrations in all these subjects. The home economics division of the Farmers' Institute school might also give instruction in the decoration of houses, beautifying the home grounds, ventilation and sanitation, and other subjects which are of special interest to women on the farm. There is at the time a great demand from the people in various parts of the State for more extended opportunities for agricultural education and for many demonstration farms which shall be near at hand in order that they may be of greater value to the locality. It is probable that the Farmers' Institute school would come nearer to furnishing the information required at a minimum cost than any other plan which can be devised, and that even tho other methods of distributing agricultural knowledge are thought to be necessary the Farmers' Institute school as a means of disseminating such knowledge should not be overlooked.

During the present year the Boys' and Girls' Agricultural Clubs, under the joint supervision of the Farmers' Institute Department and the State Department of Public Instruction, have held a large number of Institutes, at which about 11,000 boys and girls were in attendance.

Various agricultural societies meet at the University each year under the name of Organized Agriculture, the following societies participating: Association of Agricultural Students, State Veterinary Medical Association, Poland-China Breeders' Association, Duroc-Jersey Breeders' Association, Red Polled Breeders' Association, Aberdeen-Angus Breeders' Association, State Board of Agriculture, State Horticultural Society, State Poultry Association, Nebraska Dairymen's Association, State Swine Breeders' Association, State Bee Keepers' Association, State Home Economics Association, Improved Live Stock Breeders' Association, Corn Improvers' Association, Shorthorn Breeders' Association, and Farmers' Institute Conference.

PUBLICATIONS

Bulletins giving the results of investigation in the Experiment Station are published in editions of 20,000 to 25,000 each, and are distributed free of charge to any resident of the State making application. There is at the present time a regular mailing list within the State of about 16,500 names. These are continually being added to, and it is desired that all farmers who are interested in the publications of the Station should ask to be placed on the regular mailing list. The publications of the Station since those named in the last Annual Report are as follows:

Twenty-first Annual Report. Presented to the Governor January 29, 1908. 5,000 copies.

Bulletin No. 106 (Vol. XX, Art. VII). Does it Pay to Spray Nebraska Apple Orchards? By R. A. Emerson and F. E. Denny. Distributed May 2, 1908. 20,000 copies.

Bulletin No. 107 (Vol. XXI, Art. I). Part I, Foods Supplementary to Corn in Fattening Pigs; Part II, The Effect of Food on Breaking Strength of Bones. By E. A. Burnett, Director. Distributed December 1, 1908. 25,000 copies.

Bulletin No. 108 (Vol. XXI, Art. II). Milking Machines. By A. L. Haecker and E. M. Little. Distributed December 7, 1908. 8,000 copies.

Bulletin No. 109 (Substation Bulletin No. 4) (Vol. XXI, Art. III). Crop Production in Western Nebraska. Principles of Cultivation. By W. P. Snyder and W. W. Burr. 25,000 copies. (In press.)

Press Bulletin No. 28. Bunt, or Stinking Smut of Wheat. By F. D. Heald. Distributed April 15, 1908. 5,000 copies.

Press Bulletin No. 29. Pocket Gophers. By Lawrence Bruner. Distributed May 1, 1908. 25,000 copies.

ACKNOWLEDGEMENTS

The agricultural press, especially those papers located within the State, have shown their appreciation of the work of the Experiment Station by giving liberal space to the experimental work reported and in every way facilitating the extension of useful agricultural knowledge.

THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA

FINANCIAL STATEMENT

HATCH FUND

RECEIPTS

Received by the University (state) treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1908, under the act of Congress approved March 2, 1887 (Hatch fund).....	15,000 00	
EXPENDITURES		
Salaries		9,571 95
Labor		1,050 08
Publications		2,242 95
Postage and stationery		408 46
Freight and express		27 69
Chemical supplies		68 47
Seeds, plants and sundry supplies		112 51
Feeding stuffs		939 69
Tools, implements and machinery		86 50
Furniture and fixtures		181 00
Scientific apparatus		217 96
Traveling expenses		77 74
Contingent expenses		15 00
	$15,000 00	15,000 00

FINANCIAL STATEMENT—Continued

ADAMS FUND

RECEIPTS

Received by the University (state) treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1908, under the act of Congress approved March 16, 1906 (Adams fund)....	9,000 00	

EXPENDITURES

Salaries		7,232 70
Labor		255 76
Postage and stationery		18 75
Freight and express		48 50
Chemical supplies		266 50
Seeds, plants and sundry supplies		270 10
Feeding stuffs		6 00
Library		6 80
Tools, implements and machinery		138 80
Scientific apparatus		616 55
Live stock		50 00
Traveling expenses		45 14
Buildings and land		44 40
	$9,000 00	9,000 00

FINANCIAL STATEMENT—Continued

SUPPLEMENTAL FUNDS

RECEIPTS

Monies received by the University (state) treasurer from other sources than the United States, for the use and benefit of the experiment station and substation, for the year ended July 31, 1908.

Balance, July 31, 1907	5,304 37	
Sales of stock, produce, etc	23,711 80	
EXPENDITURES		
Salaries		2,596 35
Labor		2,615 64
Postage and stationery		465 54
Freight and express		860 54
Chemical supplies		92 74
Seeds, plants and sundry supplies		2,170 29
Feeding stuffs		5,712 96
Tools, implements and machinery		882 51
Furniture and fixtures		126 00
Scientific apparatus		841 51
Live stock		4,290 71
Traveling expenses		396 11
Land rent		100 00
Buildings (repairs and improvements)		1,006 69
Balance, July 31, 1908		6,858 58
	$29,016 17	29,016 17

FINANCIAL STATEMENT—Continued

APPROPRIATIONS BY THE STATE

SUBSTATION (NORTH PLATTE)

Balance, November 30, 1907, of legislative appropriation from the state general fund for benefit of the experimental substation at North Platte, for the two years ending March 31, 1909	8,837 90	
Expenditures, one year to November 30, 1908, for superintendence, supplies, labor, live stock, feed, seeds, machinery, tools and betterments of the plant		8,837 90
	$8,837 90	8,837 90

FARMERS' INSTITUTES

Balance, November 30, 1907, of legislative appropriation from the state general fund for maintenance of farmers' institutes, for the two years ending March 31, 1909	17,916 55	
Expenditures, one year to November 30, 1908, for superintendence, clerical service, labor, lecturers' and workers' services and expenses, printing, supplies		11,161 93
Appropriation balance, November 30, 1908		6,754 62
	$17,916 55	17,916 55

J. S. DALES

THE LIFE-HISTORY AND PARASITISM OF DIPLODIA ZEAE (SCHW.) LÉV.*

F. D. HEALD,† E. M. WILCOX, AND VENUS W. POOL.

INTRODUCTION.

The Nebraska Experiment Station has, for several years, been engaged in an investigation of the "corn-stalk" disease in its various phases. The Department of Agricultural Botany, as [7] its share of the problem, has made an extensive study of various fungi associated with moldy corn. One of these fungi, *Diplodia zeae,* has been shown by this investigation to be the cause of a very serious "dry-rot" of the ear and to affect other parts of the corn plant. It is deemed best to publish at this time an account of this species, which has been under investigation here over two years,[7] and postpone the publication of our studies of other corn-mold fungi to some subsequent time.

SYMPTOMOLOGY.

Diplodia zeae produces in the ear a condition which may be called "dry-rot," tho probably the majority of corn-growers refer to such ears as molded. In the early stages of this rot or in cases of slight attacks, no external evidence of the presence of the fungus can be detected. The kernels in such cases may have a perfectly healthy appearance. However, if a kernel be removed from such an ear one finds a thin whitish covering of the mycelium about its tip, and upon breaking the ear flaky masses of mycelium may be seen on the surface of the corneous margins of the alveoli.

In more advanced stages of the rot the following characters are very prominent:

1. The ear is very light in weight, shriveled up and darker in color, as compared with a healthy ear.

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*Submitted for publication November 3, 1908; preprints distributed January 1, 1909.

†Dr. F. D. Heald severed his connection with this Experiment Station on September 1, 1908. Dr. E. M. Wilcox has prepared the manuscript for the printer.

2. The kernels are either dull in color or have a dried, brown appearance. They become more brittle and are loosely attached to the cob.

3. White flaky masses of mycelium occur between the kernels and in the sulci. (See Pl. I, fig 2.) Imbedded in these flaky masses of mycelium may be found the black pycnidia.

4. The most characteristic feature is the occurrence of pycnidia on the surface of the corneous margins of the alveoli. (See Pl. IV.)

PYCNIDIA.

The pycnidia are black and spherical to pyriform. The pycnidia formed on the husk or stalk develop within the tissues and break thru the epidermis at maturity. (See Pls. VII and X). This is typical of the species as described by Schweinitz and Berkeley. However, the vast majority of the pycnidia in our plant, as formed in nature, occur between the kernels and all these are situated in a stroma. In this latter respect our fungus is related particularly to the genera *Microdiplodia, Diplodiella and Botryodiplodia,* all of which have superficial pycnidia.

CONIDIA.

The conidia are dark brown, cylindrical to elliptical, obtuse, straight or usually slightly curved and 1-(rarely 2-) septate. (See Pl. IX, fig. 16.) One to several oil drops occur in each cell. Size 24-33=5 microns. These spores germinate in eighteen to twenty-four hours on 3 per cent glucose agar (+10) at 26° C.; a somewhat longer time is required when they are grown on corn agar. A germ-tube arises from or near the distal end of each cell of the spore. (See Pl. IX, fig. 15.)

CULTURAL CHARACTERS.

When grown on glucose agar, agar, glycerin agar, Irish potato or carrot one gets a white, cottony growth of the fungus but pycnidia are not formed. On corn agar, corn-meal (see Pl. VIII, fig. 13) or sterilized corn-stalks (see Pl. VIII, fig. 14), however, the pycnidia are produced in great abundance. Pycnidia are formed* also upon peptoneless agar and glucose agar containing +10 citric acid.

---

*This observation was made by Miss Ethel C. Field, a graduate student in this Department.

EFFECT OF DIPLODIA ON THE WEIGHT OF THE EAR.

The following table shows the great loss in weight resulting from the action of this fungus. The reduction in weight applies particularly to the kernels and not to the cob:

Ear No.	Length	Av. wt. of corn on ear of this length	Wt. of corn on moldy ear of this length
	Inches	*Ounces*	*Ounces*
1	9–10	13.0	6.9
2	8–9	11.5	5.4
3	8–9	11.5	3.7
4	8–9	11.5	6.1
5	7–8	9.5	4.0
6	7–8	9.5	4.8
7	6–7	8.0	3.7
8	6–7	8.0	2.8
9	6–7	8.0	2.3
10	6–7	8.0	3.4
Average weight of corn per ear..		...... 9.8	4.3

As will be seen the loss of weight is over 50 per cent.

EFFECT OF DIPLODIA UPON INDIVIDUAL KERNELS.

It is probable that the hyphae enter the kernel at its base, since the fungus is first detected in this region. From this point the hyphae grow thruout the kernel and are found in both the endosperm and embryo. Thru the action of an enzyme, either secreted by the fungus or by the diastase-secreting cells of the embryo as a result of the fungus stimulation, the starch grains are corroded (see Pl. IX, figs. 17-19) and finally completely destroyed. The type of corrosion is the same as that due to the "diastase of secretion." The starch grains in the embryo are the first to show corrosion and disappear.

Not only does the fungus use up much of the food stored in the kernel but at the same time the viability of the kernels is completely destroyed as was shown by germination tests.

PARASITISM OF DIPLODIA.

To learn something of the parasitism of the fungus and determine the prevailing natural method of infection the following inoculations* were made during the summer of 1908. These inoculations were made as follows:

Among the silks	139
Into stalk (puncture)	31
Into husks (puncture)	46
Between husks	104
Total	320

The general results of these inoculation experiments may be stated as follows:

1. Puncture inoculations into the husks, at about the time of pollination, produce typical dry-rot ears. (See Pl. III.)

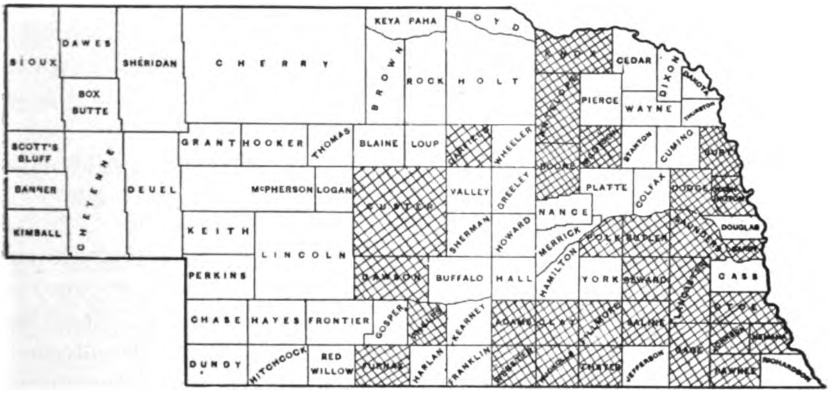
2. Puncture inoculations into the stalk resulted in the development of typical immersed pycnidia. (See Pl. X.)

3. When the fungus mycelium is simply placed among the silks, near the time of pollination, more typical Diplodia-ears were secured than by any other method. (See Pl. II.) This seems evidently to be the prevailing method by which this fungus enters the ear.

4. Little or no infection takes place from one ear to another during the same season. In other words, all the ears are infected at about the same time. The pycnidia are mature between two and three weeks after infection occurs and by this

DISTRIBUTION OF DIPLODIA ZEAE.

The known distribution of this dry-rot of corn in Nebraska is shown graphically by the map below. Counties from which specimens of this rot have been examined are indicated by the line-shading. No special effort has been made to learn its distribution outside of Nebraska. Burrill and Barrett[3] report it from Illinois and it is no doubt present in other states.



SYNONOMY AND RELATIONSHIP.

The following original descriptions are quoted to show the synonomy of the plant under consideration:

1834 *Sphaeria zeae* Schweinitz.[10]

> "*S. zeae*, L. v. S., Syn. Car. 79y, rara sed bene distincta in caulibus Zeae, Salem et Bethl. S. omnino tecta, epidermide fusco tinta (ostiolis solis prominulis) satis elevata. Seriatim disposita, brevis, utrinque acuminata, subconfluens. Peritheciis binis vel ternis tantum in caespitulo, subdistantibus, primum albofarctis, demum evacuatis. Ostiolis latis, umbilicatis, saepe unico."

1847. *Sphaeria maydis* Berkeley.[2]

> "*Sphaeria* (Seriatae) *maydis*, n. sp.; maculis parvis subellipticis elevatis; peritheciis paucis; ostiolo unico conico; sporidiis oblongis curvulis uniseptatis.
>
> "On dead culms of Zea mays. Cincinnati, Ohio. May 1, 1841. *T. G. Lea, Esq.*

"Habit that of *Sphaeria arundinacea.* Spots minute' often purple-brown, punctiform, or subelliptic, rarely linear, containing very few perithecia, with a single broad conical ostiolum. Sporidia oblong, slightly curved, uniseptate. Very different from *Sphaeria zeae,* Schwein! as appears from an authentic specimen in Sir W. Hooker's Herbarium."

1848 *Diplodia zeae* Léveillé.[8]

"*Diplodia zeae,* nov. sp. Conceptaculis gregariis innatis ovatis intus extusque nigris epidermide nigra tectis, ostiolis erumpentibus acutis; sporis elliptico-elongatis rectis vel curvatis subopacis.—Hab. Tete de Buch prope Burdigalam ad culmos *Zeae maydis.*

"*Sphaeria zeae* Schweinitz Syn. fung. North Amer., p. 207.

"*Sphaeria dolosa* Pers. (herb. Lugd. Batav.)

"*Desc.* Conceptacles assez rapprochés, globuleux au ovales, nichés dans l'épaisseur du chaume, et recouverts chacun par une portion d'épiderme noir. Ostioles aigus, proéminents à travers la rupture de l'épiderme. Substance interieure de couleur noire, composee de spores allongées, obtuses à une extrémité, aigues a l'autre, droites au courbées, avec une cloison mediane."

1884 *Diplodia maydis* (Berkeley) Saccardo.[9]

"Peritheciis gregariis, innatis, ovatis, intus extusque nigris, epidermide nigra tectis, ostiolis erumpentibus, conico-acutis; sporulis elliptico-cylindraceis, utrinque obtusiusculis subinde clavulatis, rectis vel curvulis, 1-septatis, vix constrictis, 25-30=6, fuligineis.

"Hab. in culmis, interdum pallide maculatis, *Zeae maydis* in Carolina, Ohio, New Jersey, Gallia, Italia frequens."

Currey[4] gives (l. c. Pl. 59, fig. 128) a drawing of the spores

Léveillé quotes *Sphaeria zeae* Schweinitz as the type of his new combination. Therefore according to the law of priority the name should now be written *Diplodia zeae* (Schw.) Lév. and not as given by Saccardo.

Our species seems to be related to the following two species in particular, both of which occur on *Zea mays*:

Diplodia macrospora Earle,[5] from which it differs by the much shorter spores.

Diplodia frumenti E and E.,[6] from which it differs in having much longer spores.

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PLATE I.

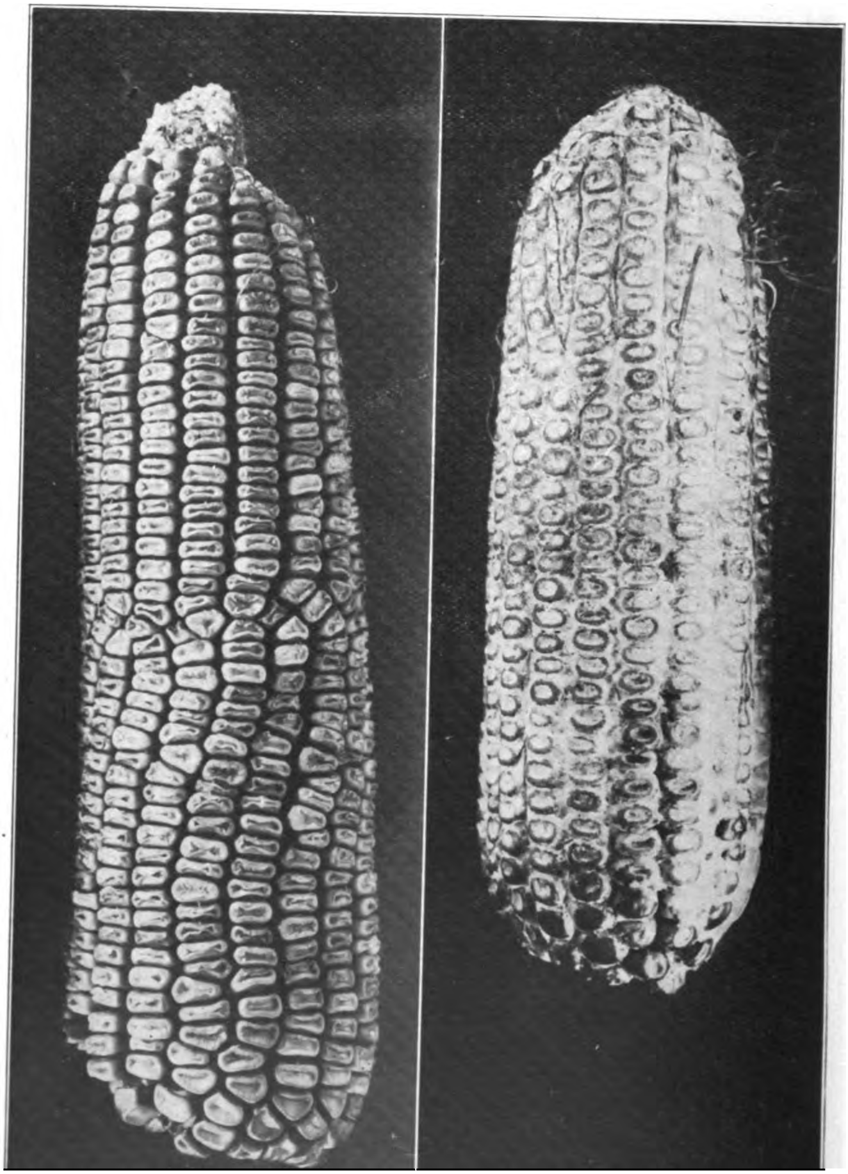


PLATE II.

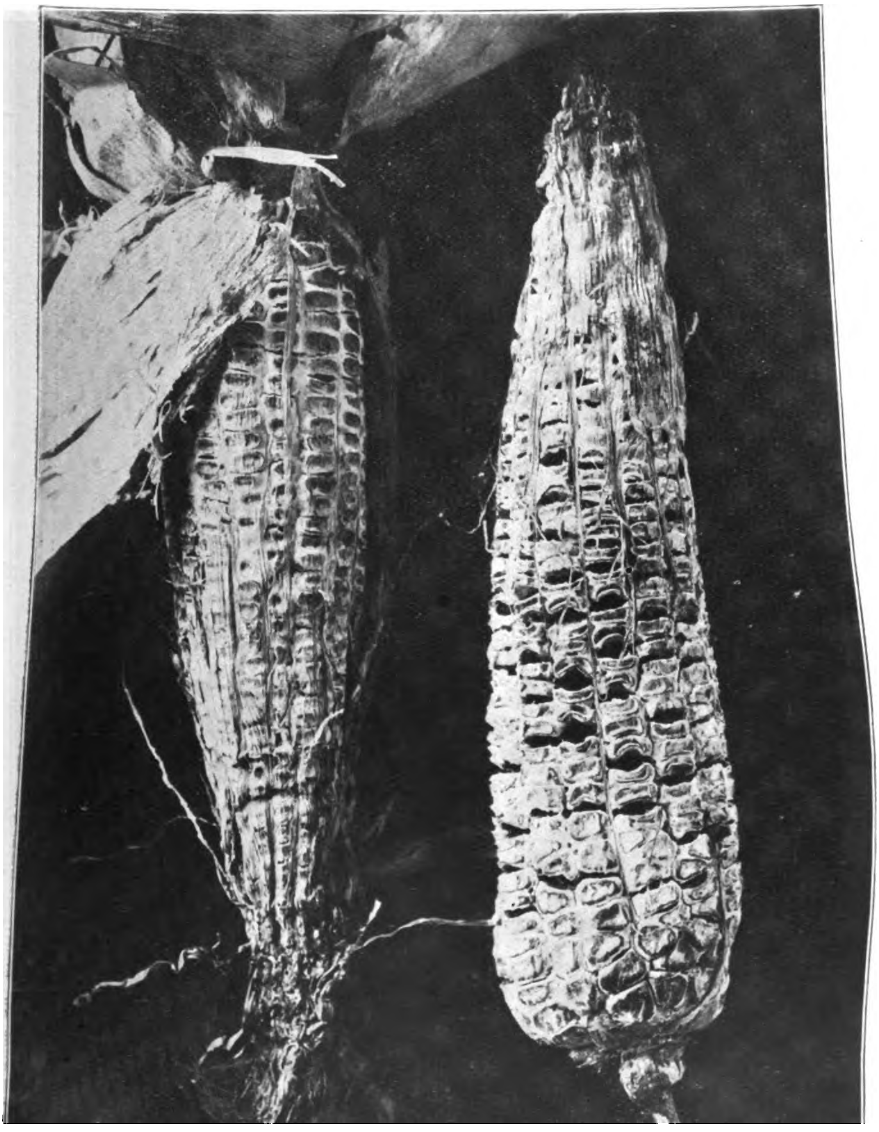


PLATE III.

PLATE IV.

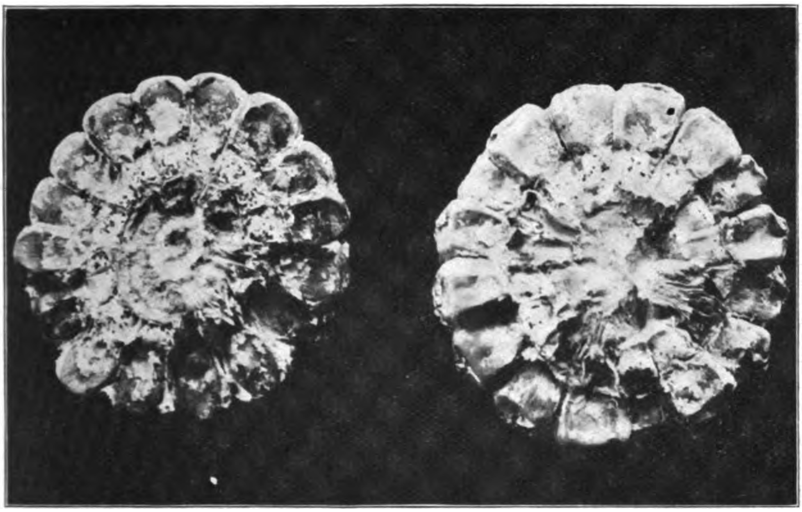


Fig. 6. Fig. 7.

The typical location of pycnidia on the opposed surfaces of the margins of the corneous alveoli of naturally inoculated ears.

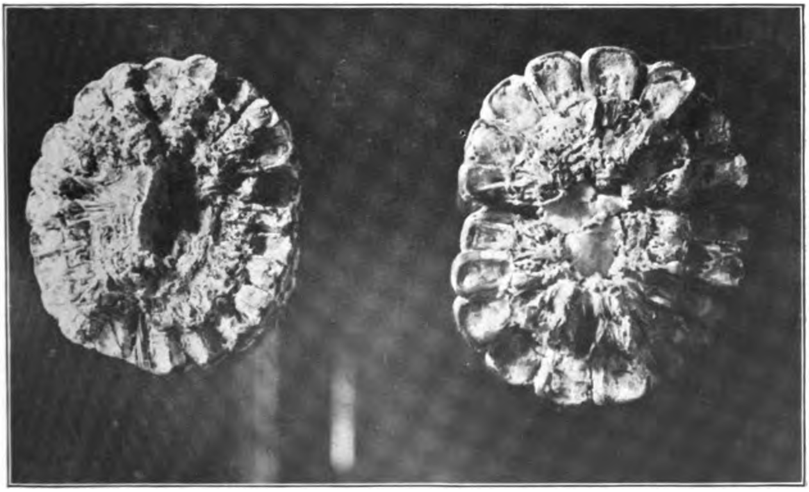


Fig. 8. Fig. 9.

The same location of pycnidia in artificially inoculated ears.

PLATE V.

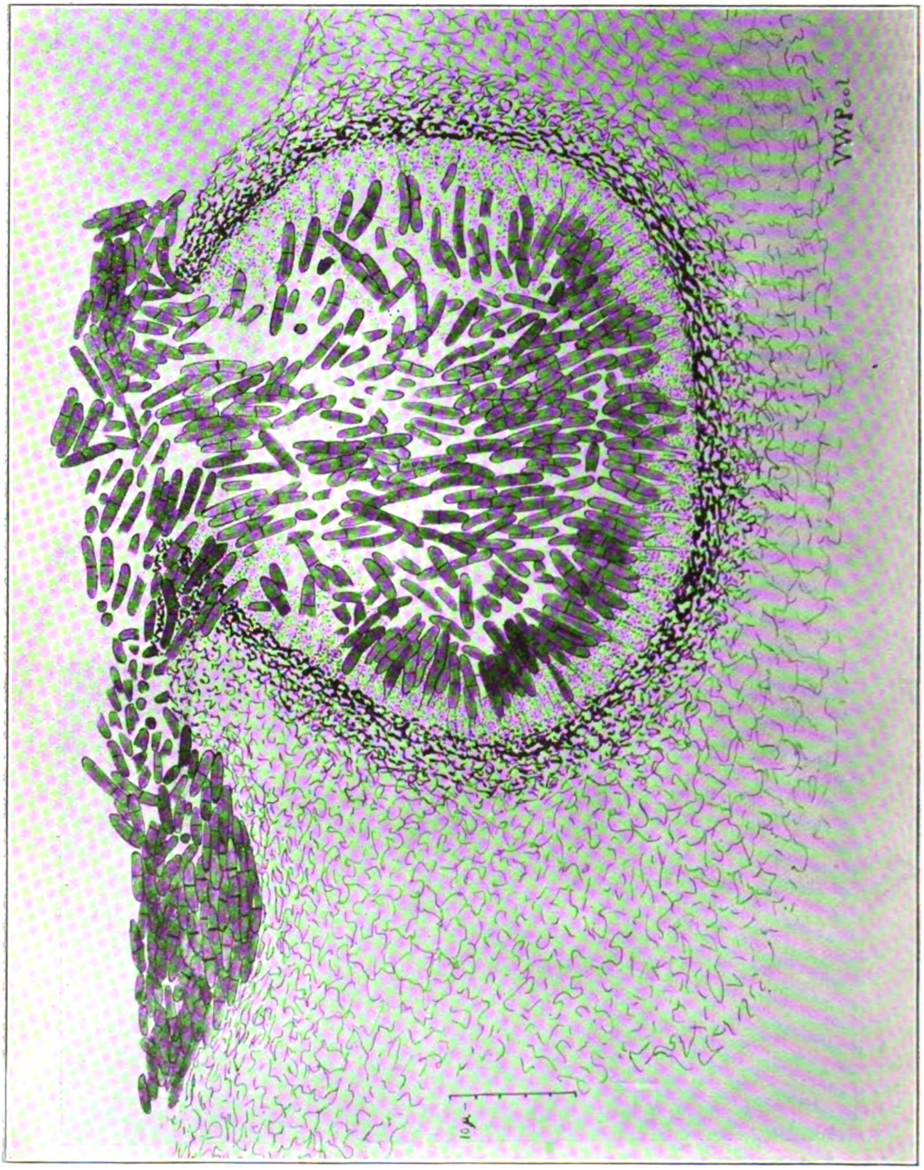


Fig. 10. Pycnidium in the stroma with escaping conidia. Note the accumulation of spores near ostiole giving blackish color to that region.

PLATE VI

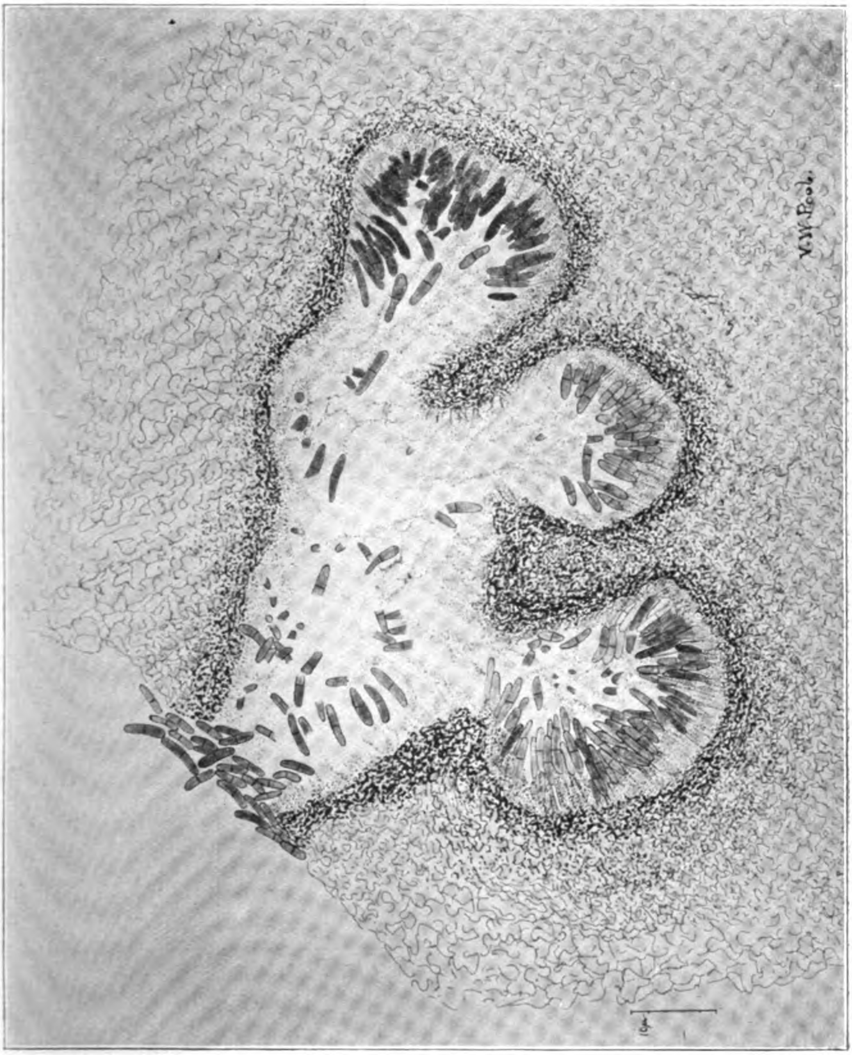


Fig. 11. A 3-locular pycnidium in the stroma.

PLATE VII.

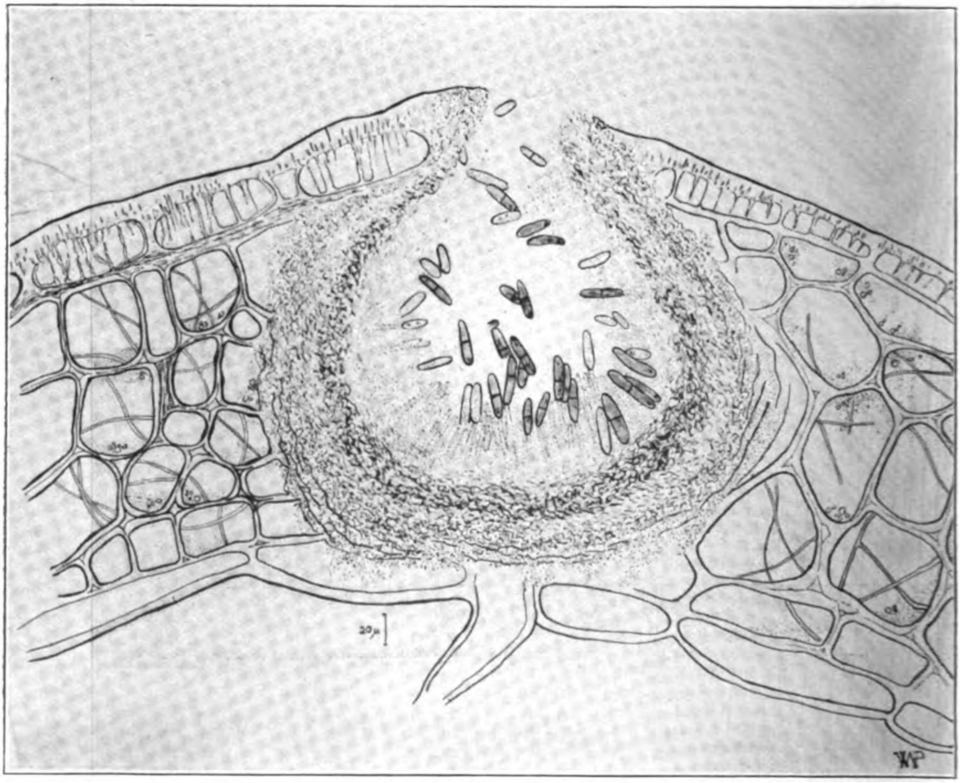


Fig. 12. An immersed pycnidium in a husk resulting from artificial inoculation.

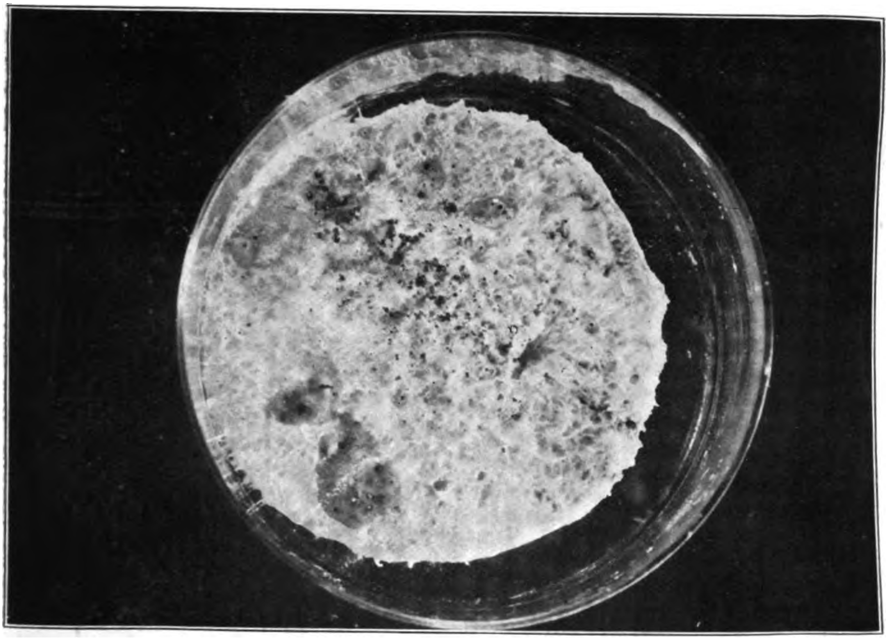


Fig. 13. Pure culture on corn-meal cake.

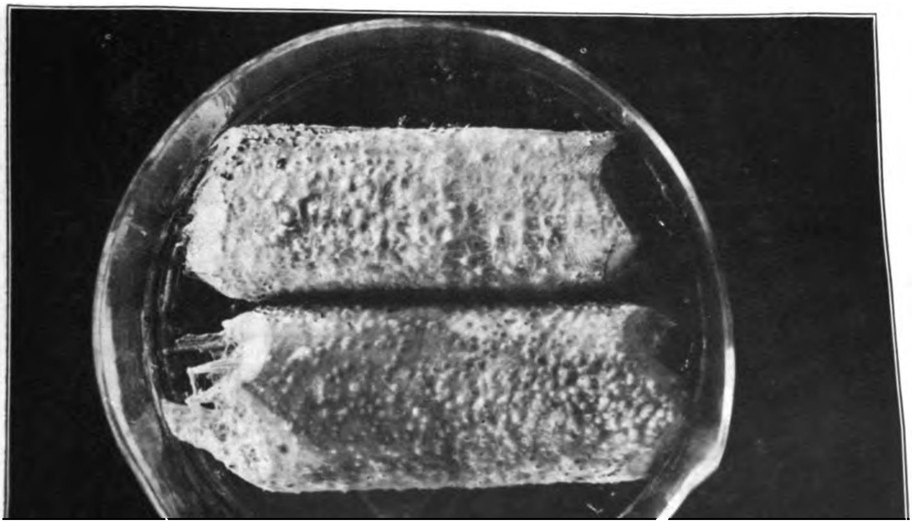


PLATE IX.

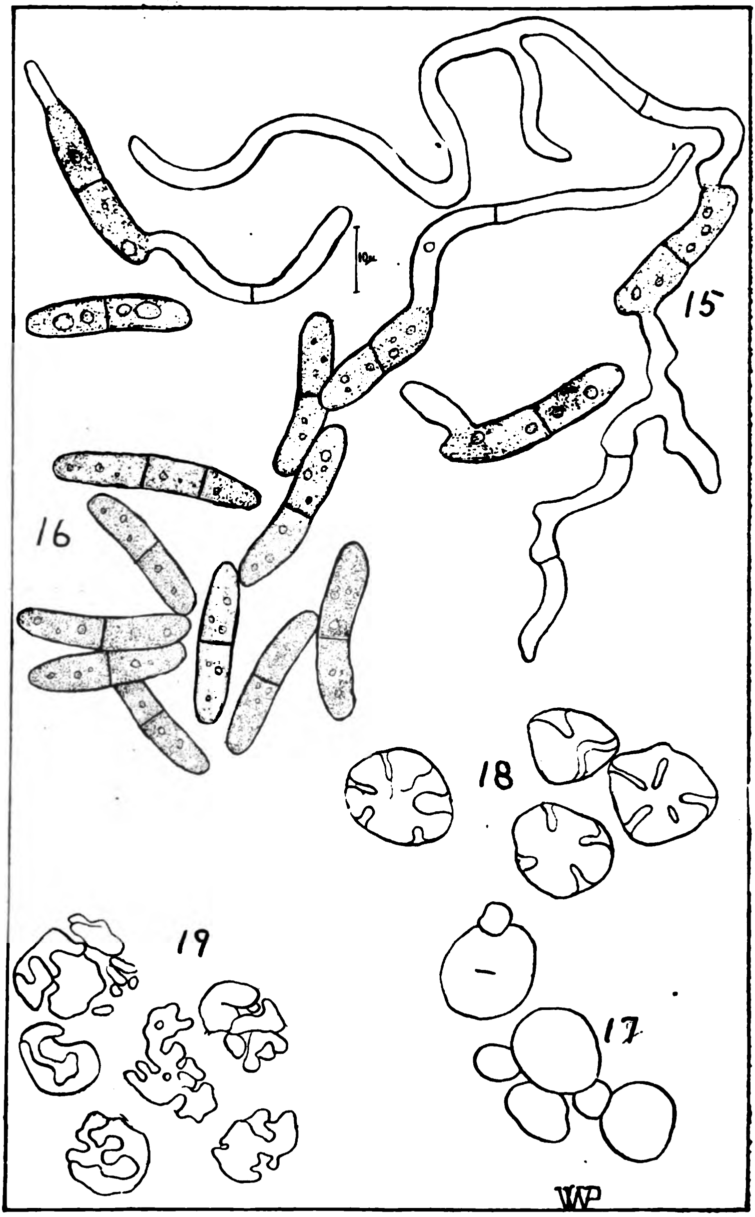


PLATE X.

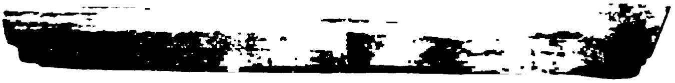
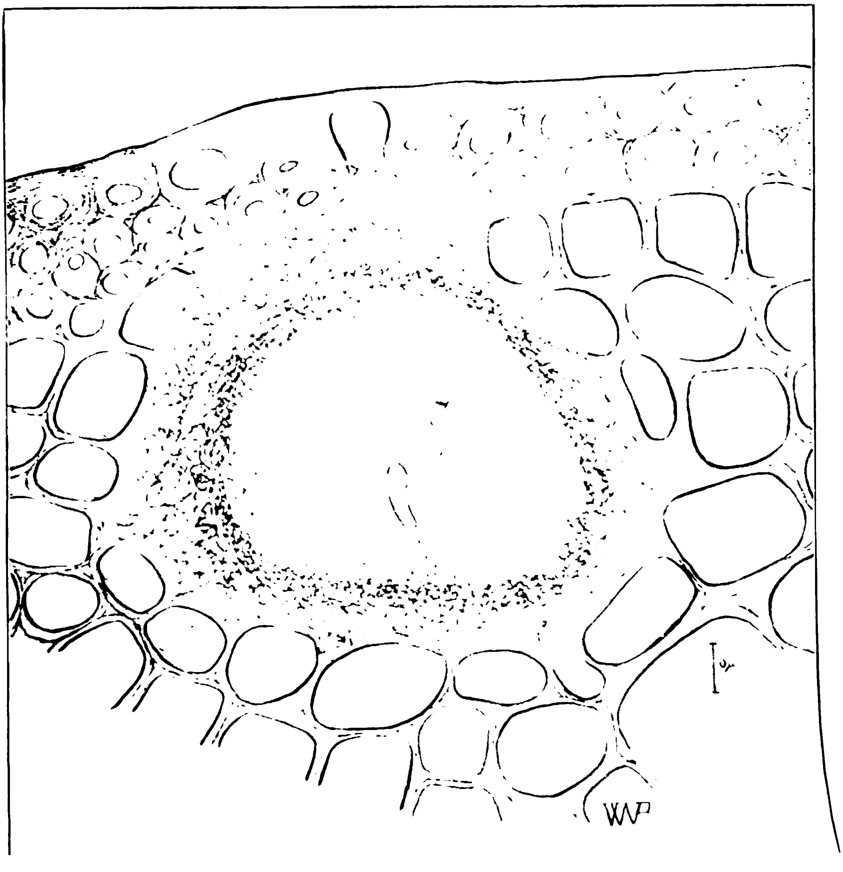


Fig. 20. Portion of an artificially inoculated corn-stalk. Around the inoculation puncture (X) the epidermis is removed to show the pycnidia.



DIRECTIONS FOR THE CONTROL OF NEBRASKA PLANT DISEASES.

BY
E. MEAD WILCOX, PH. D., PROFESSOR OF AGRICULTURAL BOTANY
AND
R. E. STONE, M. SC., ADJUNCT PROFESSOR OF AGRICULTURAL BOTANY.

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DIRECTIONS FOR THE CONTROL OF NEBRASKA PLANT DISEASES.

By E. Mead Wilcox and R. E. Stone.

INTRODUCTION.

The rapidly growing interest in the control of plant diseases has led the Botanists of various Experiment Stations to prepare so-called "Spray Calendars" for use in their respective states. This publication has been prepared to meet this need in Nebraska. We believe the method of treatment is such as to render the material of the greatest value to farmers and fruit growers. Our plan has been to state very clearly and briefly the following points regarding each of the diseases mentioned:

A. Symptoms and Cause of the disease.
B. Methods of Control or Prevention.
C. Bibliography containing references to some of the most recent or useful literature generally accessible to farmers and fruit growers.

The diseases are arranged alphabetically by their prevailing common names under the various crops, which are also arranged in the same manner. The scientific names of the various crops and of the fungi causing the various diseases are given for the reason that only in this manner can any misunderstanding be avoided.

FUNGICIDES.

At this point only such fungicides are described as require special directions for their preparation. Other simpler formulas are given in connection with the special diseases.

AMMONIACAL COPPER CARBONATE.

Copper carbonate	8 ounces
Ammonia	3 pints
Water	50 gallons

Dilute the ammonia with water and add the copper carbonate. Use just enough of the ammonia to dissolve the precipitate formed. Dilute with water to make 50 gallons.

BORDEAUX MIXTURE.

We give here only the following standard mixture, often referred to as 5-5-50 Bordeaux. The other formulas mentioned in the text are prepared in the same manner by changing the amounts of the lime and copper sulfate.

Copper sulfate (blue vitriol)	5 pounds
Quicklime (not slaked)	5 pounds
Water	50 gallons

1. Dissolve the copper sulfate in a wooden vessel, using about ten gallons of warm water. Dilute to twenty-five gallons before mixing.
2. Slake the lime very carefully with a small amount of water and then dilute to twenty-five gallons before mixing.
3. Pour the above two solutions thru a strainer at the same time into a barrel.

LIME-SULFUR WASH.

This is widely used as an insecticide but its value, in certain cases, as a fungicide warrants us in including it here.

Sulfur	15 pounds
Lime	20 pounds
Water	40 gallons

Slake the lime and then add the sulfur together with enough water to permit of easy handling. Boil the mixture till the sulfur is dissolved. Strain and add water to make the desired volume. Apply while fresh.

LIME-SULFUR WASH (SELF-BOILED).

Sulfur ("flowers" or flour)	10 pounds
Lime (fresh)	15 pounds
Water	50 gallons

"Place the lime in a 50-gallon barrel and pour a 2 or 3 gallon bucket of boiling water over it. Immediately add the sulfur and another bucket of hot water. The heat from the slaking lime will boil the mixture violently for several minutes. Some stirring is thrown over the top of the barrel helps to keep in the heat. The boiling will continue from twenty to thirty minutes, depending upon the quality of the lime. When the boiling ceases, dilute with cold water to make 50 gallons, stir thoroly and strain thru a sieve of about 20 meshes to the inch in order to take out coarse particles of lime, but all the sulfur should be carefully worked thru." (Scott 1908, p. 7.)

POTASSIUM SULFID.

Potassium sulfid	3 ounces
Water	10 gallons

Dissolve the potassium sulfid in a gallon of warm water and then dilute to the desired amount. This solution will not keep long and should be made up fresh each time you desire to spray with it.

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1908 Spraying Calendar. Bul. Nebr. Insect Pest and Plant Disease Bureau **1**:1-12. Fig. 1-2.
Fairchild, D. G.
1894 Bordeaux Mixture as a Fungicide. Bul. Div. Veg. Phys. and Path. U. S. Dept. Agr. **6**:1-55.
Haywood, J. K.

JOHNSON, W. G., TOWNSEND, C. O. AND GOULD, H. P.
1900 Some Important Insecticides, Fungicides and Apparatus for their Application. Bul. Md. Exp. Sta. **65**:55-89. Fig. 12-30.
SCOTT, W. M.
1908 Self-boiled Lime-sulfur Mixture as a Promising Fungicide. Circ. Bur. Plant Indus. U. S. Dept. Agr. **1**:1-18. Fig. 1-2.
SMITH, R. I.
1906 Spraying to Control or Prevent Injury from Insects and Plant Diseases. Insecticides and Fungicides. Bul. Georgia State Bd. Entom. **19**.
STEVENS, F. L. AND WOGLUM, R. S.
1906 Spraying Mixtures and Machinery. When and How to Spray. Bul. N. Car. Exp. Sta. **193**:1-32. Fig. 1-7.
STUBENRAUCH, A. V.
1902 Important Details of Spraying. Bul. Ill. Exp. Sta. **68**:157-188. Pl. 1-9, fig. 1-3.
SWINGLE, W. T.
1896 Bordeaux Mixture, its Chemistry, Physical Properties, and Toxic Effects on Fungi and Algae. Bul. Div. Veg. Phys. and Path. U. S. Dept. Agr. **9**:1-37.

ALFALFA (*Medicago sativa*).

DODDERS (*Cuscuta arvensis, epithymum, indecora, planiflora and racemosa chileana*).

There are five species of dodder affecting alfalfa (*Cuscuta arvensis, epithymum, indecora, planiflora* and *racemosa chileana*). The dodders are flowering plants producing seeds that are frequently found in alfalfa and clover seed. These seeds germinate in the ground and send up slender yellowish seedlings which will soon die if they do not come in contact with an alfalfa plant. They twine about the alfalfa stem and branches and develop haustoria or rootlike structures which penetrate the host plant and absorb food from it for the dodder. The lower part of the dodder soon dies and it becomes a true parasite. In the case of *Cuscuta epithymum* it has been found that the haustoria live over winter in the crown of the alfalfa. This fact renders the dodder problem a very serious one indeed.

1. Do not plant dodder seeds! Have your seed tested before planting.

2. Cut close to the ground and burn if confined to small patches.

3. If general over a field—plow up and reseed.

DEWEY, L. H.
1898 Dodders Infesting Clover and Alfalfa. Circ. Div. Bot. U. S. Dept. Agr. **14**:1-7. Fig. 1-2.

PAMMEL, L. H., BUCHANAN, R. E. AND KING, C. M.
1907 The Vitality, Adulteration and Impurities of Clover, Alfalfa and Timothy Seed for Sale in Iowa in 1906. Bul. Iowa Exp. Sta. **88**:1-69. Pl. 1, fig. 1-8.

ROBERTS, H. F. AND FREEMAN, G. F.
1906 Alfalfa Seed. Its Adulterants, Substitutes and Their Detection. Bul. Kans. Exp. Sta. **133**.

SELBY, A. D.
1903 Clover and Alfalfa Seeds. Bul. Ohio Exp. Sta. **142**.

STEWART, F. C., FRENCH, G. T. AND WILSON, J. K.
1908 Troubles of Alfalfa in New York. Bul. N. Y. Geneva Exp. Sta. **305**:331-416. Pl. 1-12.

LEAF SPOT (*Pseudopeziza medicaginis*).

This fungus causes yellowish spots on the leaves and in the center of these spots the small black fruiting bodies appear. The spores mature in early summer. Somewhat similar spots are often caused by one of the rust fungi.

1. If the disease is prevalent on young plants they should be topped, but not mowed too closely.

2. Older fields should be mowed early to avoid loss of leaves. The new growth may not be seriously affected.

CHESTER, F. D.
1891 Alfalfa Leaf Spotting. *Pseudopeziza medicaginis* (Lib.) Sacc. Rpt. Del. Exp. Sta. **3**:79-84. Fig. 7-11.

COMBS, R.
1897 The Alfalfa Leaf Spot Disease. *Pseudopeziza medicaginis* (Lib.) Sacc. Bul. Iowa Exp. Sta. **36**:858-859. Fig. 9.
1897 Alfalfa Leaf Spot Disease. *Pseudopeziza medicaginis* (Lib.) Sacc. Rpt. Iowa Exp. Sta. **1897**:155-160. Fig. 1-4.

STURGIS, W. C.
1900 The Leaf Spot of Alfalfa. Rpt. Conn. Exp. Sta. **1899**:281-282.

APPLE (*Malus malus*).

BITTER ROT OR RIPE ROT (*Glomerella rufomaculans*).

This fungus causes a brownish-red spot on the surface of the ripening fruit. This spot becomes somewhat sunken and soft and beneath it the apple has a bitter taste which gives the disease one of its common names. On the surface of this spot the dark colored summer fruiting bodies appear in near y concentric circles. From these bodies the spores escape in a pinkish gelatinous, often spirally twisted, mass. The spores are washed apart and distributed over the tree by the rain.

Cankers are developed on the twigs and in these another spore-fruit is produced. Spores from these cankers are able to infect the fruit and produce the typical bitter rot.

1. Remove cankers during the winter or early spring.
2. Pick and destroy the first apples showing this rot and the canker which is usually found just above them.
3. Spray with 4-4-50 Bordeaux mixture as follows:
    - A. Six (6) weeks after the petals fall.
    - B. Repeat after 2-3 weeks.
    - C. Repeat again after 2-3 weeks.
    - D. When bitter-rot first appears.

ALWOOD, W. B.
1894 Ripe Rot, or Bitter Rot, of Apples. Bul. Va. Exp. Station **40**:57-82. Pl. 1-2.
1902 Orchard Studies XV. The Bitter Rot of Apples. Bul. Va. Exp. Station **142**:249-279. Pl. 1-4.
BLAIR, J. C.
1907 Bitter Rot of Apples. Horticultural Investigations. Bul. Ill. Exp. Station **117**:481-551. Fig. 1-2.
BURRILL, T. J.
1907 Bitter Rot of Apples. Botanical Investigations. Bul. Ill. Exp. Station **118**:553-608. Pl. 1-10.
BURRILL, T. J. AND BLAIR, J. C.
1902 Prevention of Bitter Rot. Circ. Ill. Exp. Station **56**:1-3.
1902 Bitter Rot of Apples. Bul. Ill. Exp. Station **77**:351-366. Pl. C, fig. 1-12.
SCOTT, W. M.
1906 The Control of Apple Bitter Rot. Bul. Bur. Plant Ind. U. S. Dept. Agr. **93**:1-36. Pl. 1-8. Fig. 1.

VON SCHRENK, H. AND SPAULDING, P.
1903 The Bitter Rot of Apples. Bul. Bur. Plant Ind. U. S. Dept. Agr. **44**:1-54. Pl. 1-9. Fig. 1-9.

BLACK ROT (*Sphaeropsis malorum*).

This disease causes the mature fruits to rot and finally develop into black "mummies." Small brown spots appear on the leaves, and cankers may also develop on the branches.

1. Remove and destroy all cankers.

2. The treatment suggested for apple scab and bitter rot will control this rot.

PADDOCK, W.
1899 The New York Apple-Tree Canker. Bul. N. Y. Geneva Exp. Sta. **163**:179-206. Pl. 1-6.
1900 The New York Apple-Tree Canker. (Second Report.) Bul. N. Y. Geneva Exp. Sta. **185**:205-213. Pl. 1-4.

CROWN GALL.

On the apple there are two general types of galls, the cause of which is not as yet fully understood. These galls may be hard or soft; are most frequent near the graft union but are often found on the smaller roots even.

1. Do not plant diseased trees.

2. Remove and destroy all affected trees. Such diseased trees make little growth and will tend to spread the disease thruout the orchard.

3. Wrap the graft at the union with cloth. This will give a better union and serve to keep out bacteria, etc.

ALWOOD, W. B.
1902 Some Observations on Crown-Gall of Apple Trees. Bul. Va. Exp. Sta. **140**:185-212. Fig. 27-37.

HEDGCOCK, G. G.
1905 The Crown-Gall and Hairy-Root Diseases of the Apple Tree. Bul. Bur. Plant Ind. U. S. Dept. Agr. **90**:1-7. Pl. 1-3.
1908 Some Stem Tumors or Knots on Apple and Quince Trees. Circ. Bur. Plant Ind. U. S. Dept. Agr. **3**:1-16. Fig. 1-10.

STEWART, F. C., ROLFS, F. M. AND HALL, F. H.
1900 Hairy Root. Bul. N. Y. Geneva Exp. Sta. **191**:300-301. Pl. 2.

Von Schrenk, H. and Hedgcock, G. G.
1906 The Wrapping of Apple Grafts and Its Relation to the Crown-Gall Disease. Bul. Bur. Plant Ind. U. S. Dept. Agr. **100**:1-12.

FIRE BLIGHT OR PEAR BLIGHT (*Bacillus amylovorus*).

The bacteria causing this well-known disease enter thru wounds or by way of the flowers. They are often carried by insects from one flower to another. The leaves on the young shoots turn black and then later the twigs themselves become blackened and dead. Sunken pits or "blight cankers" are often found on the young wood. Fruit may be attacked, producing watery ulcers on the surface accompanied by decay and brown discoloration.

1. Cut out the blighted twigs as fast as they appear.
2. Cut out all blight-cankers down to the healthy bark. Wash these wounds with corrosive sublimate solution (1 part to 1000 parts of water) and paint with a heavy lead oil paint.
3. Avoid bruising or wounding of trees and treat such injuries as in "2" above.
4. Destroy or clean up all old pear and apple trees in your orchard.
5. Avoid excessive use of nitrogenous manures.
6. Plant most resistant varieties.
7. Persuade your neighbors to join with you in a campaign against this dangerous disease.

Sturgis, W. C.
1895 Fire Blight (*Micrococcus amylovorus* Burr.). Rpt. Conn. Exp. Sta. **1894**:113-117.
Whetzel, H. H.
1906 The Blight Canker of Apple Trees. Bul. N. Y. Cornell Exp. Sta. **236**:99-138. Fig. 49-84.

FLY SPECK (*Leptothyrium pomi*).

The fungus forms groups of several small black spots on the surface of the apple, hence the name of disease. Often associated with the sooty blotch.

1. Spray as for apple sooty blotch.

HAIRY ROOT.

Rosettes of very small roots spring from the main root and there are few if any large branch roots on affected trees. Compare the suggestions as to control given for apple crown-gall.

RUST (*Gymnosporangium juniperi-virginianae*).

Orange colored spots appear on the leaves. In these spots small black specks will be formed on the upper surface and several small fringed cups will project from the lower surface. The apple becomes infected by spores produced in the yellowish gelatinous spines of the "cedar apple" which appears on red cedars in the spring.

1. Cedar trees in the neighborhood must be treated in either of the following methods:
    - A. Cut down and burn.
    - B. Cut off and burn the cedar "apples." This is only practicable when but a few "apples" are present.
    - C. Spraying methods are still in doubt.
2. Plant most resistant sorts.

EMERSON, R. A.
1905 Apple Scab and Cedar Rust. Bul. Nebr. Exp. Sta. **88**:1-21. Fig. 1-9.
HALSTED, B. D.
1889 Apple Rusts. Rpt. U. S. Com. Agr. **1888**:370-381. Pl. 11-12.
HEIN, W. H.
1908 Cedar Rust, Apple Leaf Rust. (*Gymnosporangium macropus*) Circ. Div. of Bot. Nebr. Insect Pest and Plant Disease Bureau **1**:1-4. Fig. 1-4.
PAMMEL, L. H.
1905 The Cedar Apple Fungi and Apple Rust in Iowa. Bul. Ia. Exp. Sta. **84**:1-36. Fig. 1-11.
STONE, R. E.
1908 Cedar Apples and Apple Leaf-Rust. Circ. Ala. Exp. Sta. **2**:1-11. Fig. 1-2.

SCAB (*Venturia inaequalis*).

The well-known scabby spots appear on the fruit, which is not only disfigured but the broken surface of the apple near these scabs affords a good opening to other fungi to enter and produce serious rots. Scab often results in a great increase of "windfalls" and thus reduces the crop. The same fungus produces spots on the leaves and on these same leaves the "perfect" stage of the fungus develops late in the season. The twigs are at times affected.

1. Gather and burn the leaves during the fall.
2. Spray with 3-3-50 Bordeaux mixture as follows:

A. When the cluster buds are open but *before* the flowers open.

B. After the petals have fallen.

C. During a wet season—again after 7-10 days.

SOOTY BLOTCH (*Phyllachora pomigena*).

The fungus forms olive-black superficial spots on the fruit. In severe cases several of these spots may unite and thus give to the entire surface of the apple a very disagreeable color. Often this is associated with the fly-speck fungus.

1. Spray as for scab. A thoro spraying when the apples are about half grown seems best.

BARLEY (*Hordeum sativum*).

BLACK RUST OR STEM RUST (*Puccinia graminis hordei*).

The leaves and stem are first attacked and show reddish brown lines and streaks. This is the "red rust" or uredo stage. Later this is followed by a stage in which the stem and frequently the base of the leaves are covered by dark brown or black lines, often showing a distinctly ruptured epidermis. This is the "black rust" or telia stage. The rust increases very rapidly when days with light showers or heavy dew alternate with days that are sunshiny and rather hot. The grain is frequently almost destroyed. This rust occurs also on some of the native grasses such as wild barley and squirrel tail grass.

1. Destroy the native grasses around the field.

2. Other things being equal, the earlier the variety the less damage will be done by the rust.

3. Sow the seed as early as possible.

4. Sow the seed in such a manner as to give all plants an even start.

5. Use varieties which are known to be least affected by rust.

Bolley, H. L.
1889 Wheat Rust. Bul. Ind. Exp. Sta. **26**:1-19. Fig. 1-9.
1906 Rust Problems, Facts, Observations and Theories. Possible Means of Control. Bul. N. Dak. Exp. Sta. **68**:607-676. Fig. 1-30.

Carleton, M. A.
1899 Cereal Rusts of the United States. A Physiological Investigation. Bul. Div. Veg. Phys. and Path. **16**:1-74. Pl. 1-4.
1904 Investigations of Rusts. Bul. Bur. Pl. Ind. U. S. Dept. Agr. **63**:1-29. Pl. 1-2.
1905 Lessons from the Grain-Rust Epidemic of 1904. Farmers' Bul. U. S. Dept. Agr. **219**:1-24. Fig. 1-6.

Hitchcock, A. S. and **Carleton**, M. A.
1893 Preliminary Report on Rusts of Grain. Bul. Kans. Exp. Sta. **38**:1-14. Pl. 1-3.
1894 Rusts of Grain II. Bul. Kans. Exp. Sta. **46**:1-9.

Olive, E. W.
1908 Rust of Cereals and Other Plants. Bul. S. Dak. Exp. Sta. **109**:1-20. Fig. 1-5.

RED RUST OR ORANGE LEAF RUST (*Puccinia rubigo-vera simplex*).

This rust is found principally on the leaves. These become red or orange in color with a powdery appearance due to development of the spores which are usually arranged in patches rather than lines. Later small dark spots and small short lines appear on the leaves. The red spores belong to the uredo stage and the black to the telia stage. This rust develops a little earlier than the black stem rust but under practically the same conditions.

1. Apply the same remedies as suggested for the black rust.

COVERED SMUT (*Ustilago hordei*).

At harvest time the heads contain no seed but appear as dark masses. The spores do not blow away as with loose smut.

1. Secure seed free from smut.
2. If this can not be done, any of the treatments recommended for barley may be used. Among these the Modified Formalin Method is to be preferred.

Bolley, H. L.
1897 New Studies Upon the Smut of Wheat, Oats and Barley with a Resume of Treatment Experiments for the Last Three Years. Bul. N. Dak. Exp. Sta. **27**:109-162.

Clinton, G. P.
1900 Loose and Covered Smuts of Barley (*Ustilago hordei* (Pers.) Kell. and *Ustilago nuda* (Jens.) Sw.) Bul. Ill. Exp. Sta. **57**:317-318. Pl. D.

LOOSE SMUT (*Ustilago nuda*).

At harvest time the heads contain no seed but appear to be powdery masses of black spores. The spores are often blown away by the winds before this time, leaving only the bracts or scales.

Infection takes place at flowering time and the fungus grows into the embryo of the developing seed. From such an infected seed a smutted plant will develop the following year. This smut may be prevented by the Jensen modified hot-water treatment:

Soak in cold water for 5 hours; then soak in water at a temperature of 125° for 15 minutes.

Every farmer should maintain a small isolated seedplat to develop healthy seed free from smut infection. From this small plat all smutted heads should be removed and destroyed.

CLINTON, G. P.
1905 Ustilagineae or Smuts of Connecticut. Bul. Conn. State Geological and Natural History Survey. **5**.

FREEMAN, E. M. and JOHNSON, E. C.
1909 The Loose Smuts of Barley and Wheat. Bul. Bur. Plant Indus. U. S. Dept. Agr. **152**: 1-48. Pl. 1-6.

HEALD, F. D.
1908 Seed Treatment for Smuts of Winter Barley. Rpt. Nebr. Agr. Exp. Sta. **21**:45-53.

BEAN (*Phaseolus vulgaris*).

ANTHRACNOSE OR POD SPOT (*Colletotrichum lindemuthianum*).

Black specks or cankers with reddish or yellowish margins develop on the pods and leaves. Rusty red spots are also sometimes found on the seeds themselves. The fungus grows thru the pod into the seed which is in contact with it. Seedlings from diseased seed will show the canker spots on the cotyledons and then later on the pods and leaves.

1. Select seed for planting from pods free from the disease. Seed treatment is of no value.
2. Avoid cultivating the plants when they are wet.
3. Spray wet plants with 5-5-50 Bordeaux as follows:
   - A. When the plants come thru the ground.
   - B. When first pair of leaves are expanded.
   - C. When the pods have "set."
4. Rotation and destruction of diseased plants may be of some value.

EDGERTON, C. W.
1909 Preliminary Report on the Anthracnose or Pod Spot Disease of Beans. Bul. La. Exp. Sta. **116**:1-11. Fig.1-3.

FULTON, H. R.
1908 Diseases of Pepper and Beans. Bul. La. Exp. Sta. **101**:1-21. Fig. 1-15.

HALSTED, B. D.
1901 Bean Diseases and Their Remedies. Bul. N. J. Exp. Sta. **151**:1-28. Pl. 1-4, fig. 1-9.

WHETZEL, H. H.
1906 Some Diseases of Beans. Bul. N. Y. Cornell Exp. Sta. **239**:195-214. Fig. 100-115.
1908 Bean Anthracnose. Bul. N. Y. Cornell Exp. Sta. **255**:429-447. Fig. 217-222.

WILCOX, E. M. AND TEMPLE, C. E.
1909 Anthracnose of beans. Circ. Div. of Bot., Insect Pest and Plant Dis. Bureau of Nebraska. **6**:1-4. Fig.1-3.

BEET (*Beta vulgaris*).

LEAF SPOT (*Cercospora beticola*).

Small brown spots with a reddish purple margin appear on the surface of the leaf. These spots increase in size and number and in severe attacks the leaves may be killed outright. In this way the production of sugar is very much reduced.

1. Do not grow beets on the same ground two years in succession.

2. Spray with 5-5-50 Bordeaux in cases where a severe epidemic of the disease is expected.

DUGGAR, B. M.
1899 Three Important Fungous Diseases of the Sugar Beet. Bul. N. Y. Cornell Exp. Sta. **163**:335-363. Fig. 49-63.

TOWNSEND, C. O.
1902 Some Diseases of the Sugar Beet. "Report" U. S. Dept. Agr. **72**:90-101. Pl. 12-15.

SOFT ROT (*Bacterium teutlium*).

This is a bacterial rot of beets, first described from Nebraska material. Manner and place of infection are not fully understood.

1. Avoid planting beets on wet, poorly-drained land.

2. Develop resistant strains of beets.

3. Beets grown on wet soil should not be stored with those from well-drained soil.

METCALF, H.
1904 A Soft Rot of the Sugar Beet (*Bacterium teutlium* Metcalf). Rpt. Nebr. Exp. Sta. **17**:69-112. Fig. 1-5.

BLACKBERRY (*Rubus villosus*).

ANTHRACNOSE (*Gloeosporium venetum*).

Honey-colored spots with a purplish margin are produced on the leaves. Lighter colored spots are found on the petioles and canes.

1. Select new plants from healthy fields.

2. Cut out and destroy old canes and diseased new ones after the fruit is gathered.

3. Spray with 5-5-50 Bordeaux as follows:

Longyear, B. O.

1904 Anthracnose of Raspberry and Blackberry. Special Bul. Mich. Exp. Sta. **25**:51-52. Fig. 37.

Paddock, W.

1897 Anthracnose of the Black Raspberry. Bul. N. Y. Geneva Exp. Sta. **124**:261-274. 1 plate.

Sturgis, W. C.

1900 On the Prevention of Raspberry-Anthracnose by Cultural Methods. Rpt. Conn. Exp. Sta. **1899**:274-276.

CROWN GALL.

Galls or excrescences appear on the roots and lower parts of the stem.

1. Remove and destroy all affected plants.
2. Do not plant infected stock.

ORANGE RUST (*Gymnoconia interstitialis*).

The aeciaspores are orange-red in color and are produced in immense numbers on the lower surface of the leaves. The hyphae live within the tissues of the leaves, rendering treatment very difficult.

1. Dig out and burn all infected plants.
2. Spray with Bordeaux to hold the disease somewhat in check.

Longyear, B. O.

1904 Orange Rust of Raspberry and Blackberry. Special Bul. Mich. Exp. Sta. **25**:50-51. Fig. 36.

Schneider, A.

1893 Orange Rust of Raspberry and Blackberry. Bul. Ill. Exp. Sta. **29**:273-300. Pl. 1-4.

CABBAGE (*Brassica oleracea*).

BLACK ROT (*Pseudomonas campestris*).

This is a bacterial disease characterized by the development of black streaks in the woody portion of the stem and leaf stalks. Infection occurs either thru the roots, the leaves, or at the base of the leaf close to the stem. The germs may live over winter attached to the seeds.

1. Practice crop rotation.
2. Soak the seeds before planting for 15 minutes in either:
   - A. A solution of 1 ounce of corrosive sublimate in 1000 ounces of water.
   - B. A solution of 1 pound of formalin in 30 gallons of water.

Harding, H. A., Stewart, F. C. and Prucha, M. J.
1904 Vitality of the Cabbage Black Rot Germ on Cabbage Seed. Bul. N. Y. Geneva Exp. Station. **251**:177-194. Pl. 1.

Russell, H. L.
1898 A bacterial rot of cabbage and allied plants. Bul. Wis. Exp. Station. **65**:1-39. Fig. 1-15.

Smith, E. F.
1898 The Black Rot of the Cabbage. Farmers' Bul. U. S. Dept. Agr. **68**:1-21.

Stewart, F. C. and Harding, H. A.
1903 Combating the Black Rot of Cabbage by the Removal of Affected Leaves. Bul. N. Y. Geneva Exp. Station **232**:43-65. Pl. 1-2.

CARNATION (*Dianthus caryophyllinus*).

BUD ROT (*Sporotrichum poae*).

This fungus attacks the flower buds and renders the flower of no value. A species of mite is associated with the fungus and probably aids in its distribution.

1. Gather and destroy all diseased buds.
2. Grow the most resistant varieties.

Heald, F. D.
1907 The Bud-Rot of Carnations. Bul. Nebr. Exp. Sta. **103**:3-17. Pl. 1-6.

Stewart, F. C. and Hodgkiss, H. E.
1908 The Sporotrichum Bud-Rot of Carnations and the Silver Top of June Grass. Tech. Bul. N. Y. Geneva Exp. Sta. **7**:83-119. Pl. 1-6.

RUST (*Uromyces caryophyllinus*).

On the leaves dark colored spots appear which finally rupture the epidermis allowing the black teliaspores to escape.

1. Grow only the most resistant varieties.
2. Select your cuttings from healthy plants.
3. Spray with a solution of 1 pound of copper sulfate to 20 gallons water as follows:
   A. In the field once a week.
   B. In the greenhouse once in two weeks.
4. Keep your carnation house as *dry* and *cool* as possible so that leaf surfaces are free from moisture.

Stewart, F. C.
1896 Combating Carnation Rust. Bul. N. Y. Geneva Exp. Sta. **100**:33-68. Fig. 1-2.

CHERRY (*Prunus*).

BLACK KNOT (*Plowrightia morbosa*).

The fungus enters thru wounds or cracks and develops within the branches. As a result of the growth of the fungus the tissues are stimulated to an abnormal growth; the bark is ruptured longitudinally, exposing a soft velvety cushion of fungus threads or hyphae. This cushion is at first yellowish but turns to an olive or dark yellow brown color. The surface of this knot is covered in summer with upright threads on which the summer spores are produced in large numbers. During the winter on the same knots the perfect stage develops in which spores are formed in sacs or asci developed inside of the numerous cavities in the outer part of the knot.

1. During the fall and winter cut out and burn all the knots found on cultivated and wild plums and cherries.
2. Secure the cooperation of your neighbors in waging warfare against this disease.

Beach, S. A.
1892 Black Knot of Plum and Cherry. Bul. N. Y. Geneva Exp. Sta. **40**:25-34. Fig. 1-9.
Halsted, B. D.
1891 Destroy the Black Knot of Plum and Cherry Trees. An Appeal. Bul. N. J. Exp. Sta. **78**:1-14. Fig. 1-7.
Lodeman, E. G.
1894 Black-Knot of Plums and Cherries, and Methods of Treatment. Bul. N. Y. Cornell Exp. Sta. **81**:633-656. Fig. 1-6.

BROWN ROT (*Sclerotinia fructigena*).

(See Peach—Brown Rot.)

LEAF SPOT OR SHOT HOLE (*Cylindrosporium padi*).

Spots appear on the leaf and when these diseased areas fall out it gives the leaf the appearance which is responsible for the common name shot-hole. The English Morello and Montmorency cherries are particularly susceptible. Young trees in the nursery rows are often killed outright by this disease.

1. Spray with 3-3-50 Bordeaux as follows:
   - A. Just before the blossoms open.
   - B. When the fruit is free from the calyx.
   - C. Two weeks later.
   - D. Two weeks later than "C."

HEIN, W. H.
1908 Cherry Shothole (*Cylindrosporium padi*). Circ. Div. of Bot. Insect Pest and Plant Dis. Bureau. **2**:2-4. Fig. 1.

TAFT, L. R.
1906 Cherry Leaf-Blight. Rpt. Mich. Exp. Sta. **19**-1906: 103-104.

CORN (*Zea mays*).

MOULD (*Diplodia zeae*).

This mould or rot is very frequently found in the field and in years of short crop may very seriously decrease the yield. The diseased plants may be told by the slightly greyish color and more or less mouldy appearance. The shuck sticks closely to the ear and often small black dots can be seen on the surface of the shucks. Upon tearing open the shucks the ear within is seen to be bluish grey and has a characteristic mouldy appearance. The infection takes place about the time the silks are out, the spores being brought over from the previous year. Of course the ear is of no value for feeding purposes but should not be left in the field as it will become the center of infection for the following year.

1. Remove from the field and destroy all mouldy stalks and ears.

BURRILL, T. J. AND BARRETT, J. T.
1908 Dry Rot of Corn. Circ. Ill. Exp. Sta. **117**:1-3.

HEALD, F. D., WILCOX, E. M., AND POOL, V. W.
1909 The Life-History and Parasitism of Diplodia Zeae (Schw.) Lev. Rpt. Nebr. Exp. Sta. **22**:1-7. Pl. 1-10.

STEVENS, F. L. AND HALL, J. G.
1909 A Study of Corn Mold. Rpt. N. Car. Exp. Sta. **31**:37-39.

RUST (*Puccinia sorghi*).

This rust has somewhat the appearance of the red rust of barley but each pustule is surrounded by the distinctly ruptured epidermis. The leaves are covered with reddish brown spots about a quarter of an inch long which are first red and later become dark brown. This rust is usually most prominent about the first of September. It appears too late to do much damage.

SMUT (*Ustilago zeae*).

The smut masses are first greyish and later break open and show the black powdery mass of spores. The disease may occur at the joints, on the leaves, on the tassel, and most frequently on the ear. This smut does not infect the seedling as do the smuts of oats, wheat and barley. It will infect any growing point at any time during the season. The fungus growth is entirely local. It can not be prevented by the treating of the seed.

1. Destroy all smut masses by removing from the field and burning.

2. The smut spores will germinate in fresh manure, hence avoid using fresh manure on the fields where the crop was badly smutted.

CUCUMBER (*Cucumis sativus*).

ANTHRACNOSE (*Colletotrichum lagenarium*).

Whitish spots appear on the leaves, petioles and stems. In these spots the small yellowish fruiting bodies develop.

(For Method of Control and Bibliography consult Cucumber—Downy Mildew.)

DOWNY MILDEW (*Peronoplasmopara cubensis*).

On the leaves there appear large angular yellow spots usually bounded by the veins. The oldest leaves are attacked first and the disease progresses towards the tip of the vine. Warm moist weather is favorable to the disease.

1. Spray with 5-5-50 Bordeaux as follows:
   A. When the vines begin to "run."
   B. Repeat every 10-14 days thruout the season.

CLINTON, G. P.

1905 Downy Mil[illegible] or Blight *Peronopla*[illegible]*opara cubensis*

ORTON, W. A.

1905 Spraying for Cucumbers and Melon Diseases. Farmers' Bul. **231**:1-24. Fig. 1-8.

ORTON, W. A. AND GARRISON, W. D.

1905 Methods of Spraying Cucumbers. Bul. S. Car. Exp. Sta. **116**:1-36. Pl. 1-4.

SELBY, A. D.

1897 Prevalent Diseases of Cucumbers, Melons, and Tomatoes. Bul. Ohio Exp. Sta. **89**:99-122. Pl. 1-3.

SHELDON, J. L.

1904 Diseases of Melons and Cucumbers During 1903 and 1904. Bul. W. Va. Exp. Sta. **94**:121-138. Pl. 1-5.

SIRRINE, F. A. AND STEWART, F. C.

1898 Spraying Cucumbers in the Season of 1898. Bul. N. Y. Geneva Exp. Sta. **156**:375-396. Pl. 1-5, and Rept. N. Y. Geneva Exp. Sta. **1898**:67-89. Pl. 13-17.

STEWART, F. C.

1897 The Downy Mildew of the Cucumber; What It Is and How to Prevent It. Bul. N. Y. Geneva Exp. Sta. **119**:153-182. Pl. 1-4.

1897 Further Experiments on Spraying Cucumbers. Bul. N. Y. Geneva Exp. Sta. **138**:636-644.

GOOSEBERRY (*Ribes grossulariae*).

POWDERY MILDEW (*Sphaerotheca mors-uvae*).

1. Gooseberries should be planted on well-drained ground and where there is free circulation of the air.

2. Prune off the drooping branches.

3. Destroy the weeds in the plantation.

4. Spray with a solution of 1 ounce of potassium sulfid to 2 gallons of water as follows:

   A. When the buds are opening.

   B. Repeat every week until the fruit is harvested.

CLOSE, C. P.

1897 Spraying in 1897 to Prevent Gooseberry Mildew. Bul. N. Y. Geneva Exp. Sta. **133**:489-500.

1899 Treatment for Gooseberry Mildew. Bul. N. Y. Geneva Exp. Sta. **161**:153-164. Pl. 1-2.

GRAPE (*Vitis sp.*).

BLACK ROT (*Guignardia bidwellii*).

The winter stage of this fungus is produced on the black mummied grape berry or its pedicel. The spores produced by this stage of the fungus can infect only the stem, tendril, leaf or young fruit of the grape. They will germinate and penetrate the leaf and on this produce the summer spores in small chambers called pycnidia. In the spring these same chambers produce the winter spore stage in which the spores are produced within sacs or asci.

1. Remove all "mummied" fruits when you prune the vines.
2. Plow early in the spring and turn under all old fruits and diseased leaves. Rake the rotted fruit and dead leaves, under the vines, into the furrow and cover with a hoe.
3. Practice surface cultivation and destroy weeds and grass.
4. Keep vines thoroly sprouted; if necessary sprout twice.
5. Spray with 5-5-50 Bordeaux as follows:
   - A. From the appearance of the third leaf until the middle of July.
   - B. Cover the leaves on the new growth particularly well.
   - C. Use a "trailer" after the foliage becomes dense to ensure thoro work.
6. Spray with ammoniacal copper carbonate as follows:
   - A. Middle of July.
   - B. Two weeks later.
7. In spraying use 80-100 gallons to the acre; have a pressure of at least 100 lbs. and a nozzle with a one-sixteenth inch opening in the disk.

Butz, G. C.
1904 Spraying Grapes for Black Rot in Erie County, Penna. Bul. Pa. Exp. Sta. **66**:1-16. Fig. 1-2.

Edson, A. W.
1903 The Black Rot of the Grape in North Carolina and Its Treatment. Bul. N. Car. Exp. Sta. **185**:133-156.

Reddick, D. and Wilson, C. S.
1908 The Black-Rot of the Grape and Its Control. Bul. N. Y. Cornell Exp. Sta. **253**:367-388. Fig. 177-187.

SCRIBNER, F. L.
1886 Report on the Fungus Diseases of the Grape Vine. Bul. Bot. Div. U. S. Dept. Agr. **2**:1-136. Pl. 1-7.
1891 Some Fungous Diseases of the Grape. Bul. Tenn. Exp. Sta. **IV.** Pt. 4:97-118. Fig. 1-26.
SELBY, A. D.
1901 Grape Rots in Ohio. Bul. Ohio Exp. Sta. **123**:85-94. Fig. 1-3.
1902 The Relation of Grape Spraying to Public Health. Bul. Ohio Exp. Sta. **130**:42-46.
WILSON, C. S. AND REDDICK, D.
1909 The Black Rot of the Grape and Its Control. Second Report. Bul. N. Y. Cornell Exp. Sta. **266**:391-411. Fig. 99-110.

LETTUCE (*Lactuca sativa*).

DROP OR ROT (*Sclerotinia libertiana*).

This fungus is a very active parasite of the leaves and stem and causes a very sudden "wilt" or "drop" of the plants. The small white bodies about the size of pin heads which are often found both on the stem and the soil about the dead plants are the resting stages of the fungus and serve to carry it over from one season to another. The disease is particularly injurious in greenhouse lettuce.

1. In greenhouses the best method is to sterilize the soil to a depth of 2 to 4 inches with live steam.

2. Covering the soil to a depth of 1 inch with sterilized sand or soil is very effective.

3. Maintain good ventilation and drainage in the greenhouse.

4. If the above methods are impossible use fresh, uninfected soil for each crop.

STONE, G. E. AND SMITH, R. E.
1900 The Rotting of Greenhouse Lettuce. Bul. Mass. Exp. Sta. **69**:1-40. Fig. 1-10.

OATS (*Avena sativa*).

BLACK RUST OR STEM RUST (*Puccinia graminis avenae*).

This rust very closely resembles the Black rust or Stem rust of barley and wheat. However, oats can not be attacked by barley rust nor wheat rust nor can these be attacked by oat rust.

The leaves and stems first become covered with reddish brown lines and these later turn dark brown or black. By the time the rust has become black the plants are usually very much damaged. Plenty of moisture in the form of light rains or dews followed by bright sunlight and warm weather are ideal for the rust. This disease is found on many of the native grasses also.

1. Keep down the native grasses around the field.
2. Other things being equal, the earliest varieties will be least rusted.
3. Sow seed early to have the plants mature early.
4. Sow the seed in such a manner as to give all plants an even start.
5. Use varieties which have shown themselves to be rust resistant.

(Consult Bibliography of Barley—Black Rüst.)

CROWN RUST OR RED RUST (*Puccinia coronata*).

This rust is the one most frequently found on oats. It occurs mostly on the leaves which frequently become almost crusted over with the red powdery summer spores. These also occur on the stems to some extent. Later in the season the small dark lines are formed on the leaves; these are the winter spores.

Practically the same conditions favor this rust as pointed out for the black or stem rust of oats. Oats growing in very rich soil are especially severely attacked; oats growing over stack bottoms and old stackyards.

1. The measures suggested for oat black or stem rust are useful here also.

(Consult the Bibliography of Barley—Black Rust).

HIDDEN SMUT (*Ustilago levis*).

At harvest time the heads contain no seeds but in their places are found the black smut masses. In threshing, these masses are more or less broken up and the spores scattered. Some of these spores become attached to the oat grains. These spores are sown with the grain and infection takes place only when the seedling is very small—before it appears above the ground. The fungus filaments or hyphae keep pace in their growth with that of the oat plant itself.

1. For smaller amounts of seed use either one of the methods given for barley smut, or the following for oat loose smut. The modified formalin method is the most convenient.

2. For larger amounts of seed the chimney method is more rapid and should be used whenever possible.

LOOSE SMUT (*Ustilago avenae*).

At harvest time the heads contain no seed but appear to be powdery masses of black spores. The spores are often blown away before harvest time leaving little but the empty head, sometimes only a barren stalk. The spores are sown with the seed to which they adhere. Infection can take place only when the seedling is very small. The fungus filaments or hyphae keep pace in their growth with the oat plant itself.

This smut may be prevented by any one of the methods given for barley smut. For small amounts these are very satisfactory. The Modified Formalin Method (No. 2) is the easiest to apply. Where large amounts are to be treated the Tower Method is more satisfactory.

Construct a chimney 40-50 feet high and about 3 feet square. On the inside shelves project to toss the falling grain from side to side. By means of a steam pump, formalin is thrown against the grain near the top in the form of a fine spray. The grain may be allowed to lie in a bin at the bottom of the chimney over night or removed to another bin. The next day the grain should be dried by running thru the chimney again, cold air taking the place of the formalin spray. By this means 500 bushels may be treated in an hour at a cost of ⅓ of a cent per bushel.

(Consult the Bibliography of Barley Smut and in addition the following:)

ARTHUR, J. C.
1905 Rapid Method of Removing Smut from Oat Seed. Bul. Ind. Exp. Sta. **103.**
GOFF, E. S.
1901 The Prevention of Oat Smut. Special Bul. Wis. Exp. Sta.
KELLERMAN, W. A. AND SWINGLE, W. T.
1889 Preliminary Report on Smuts in Oats. Bul. Kansas Exp. Sta. **8.**
1890 Report on Loose Smuts of Cereals. Rpt. Kansas Exp. Sta. **2.**

SWINGLE, W. T.
1892 Treatment of Smut in Oats and Wheat. Farmers' Bul. U. S. Dept. Agr. **5**.
1901 Treatment of Oats for Smut. Bul. Ill. Exp. Sta. **64**.
1907 The Prevention of Stinking Smut in Wheat and Loose Smut in Oats. Farmers' Bul. U. S. Dept. Agr. **250**.

ONION (*Allium cepa*).

SMUT (*Urocystis cepulae*).

This smut first appears as black lines on the green foliage leaves but may also develop on the scales of the bulb.

1. Clean sets when planted in clean soil rarely have smut.
2. Practice crop rotation.
3. When planting seeds drill into the rows 100 pounds of sulfur and 50 pounds of air-slaked lime to the acre.

HALL, F. H., SIRRINE, F. A. AND STEWART, F. C.
1900 Sulphur and Lime for Onion Smut. Bul. N. Y. Geneva Exp. Sta. Pop. Edit. **182**:1-8.

SELBY, A. D.
1901 Onion Smut. Preliminary Experiments. Bul. Ohio Exp. Sta. **122**:71-84.
1902 The Prevention of Onion Smut. Bul. Ohio Exp. Sta. **131**:47-51.

SIRRINE, F. A. AND STEWART, F. C.
1900 Experiments on the Sulphur-Lime Treatment for Onion Smut. Bul. N. Y. Geneva Exp. Sta. **182**:145-172. Pl. 1.

PEA (*Pisum sativum*).

LEAF SPOT, POD SPOT OR BLIGHT (*Ascochyta pisi*).

The fungus attacks the stem of the seedling near the ground and in severe cases the plants may wilt and die, particularly in dry weather. Diseased spots appear on the leaves and if the disease is severe some of the leaves may die. On the pods there may appear cankers or spots resembling very much those of the bean anthracnose. The fungus, like the anthracnose fungus, grows thru the pod and into the seeds in which it will winter over.

1. Plant none but healthy seed from healthy fields.
2. Tying up the vines and spraying with Bordeaux mixture will prove of value in securing healthy seed peas.

HALSTED, B. D.
1894 Some Fungous Diseases of the Pea. Rpt. N. J. Exp. Sta. **1893**:357-362. Fig. 30-32.

VAN HOOK, J. M.
1906 Blighting of Field and Garden Peas. Powdery Mildew of the Pea. Bul. Ohio Exp. Sta. **173**:231-249. Fig. 1-12.

POWDERY MILDEW (*Erysiphe communis*).

This disease may be recognized by the whitish coating formed by the mycelium of the fungus on the leaves and stems. The fungus may live over winter on the seed.

1. Spray with 5-5-50 Bordeaux as soon as the disease appears and at intervals of a week until the trouble disappears.

VAN HOOK, J. M.
1906 Powdery Mildew of the Pea. Bul. Ohio Exp. Sta. **173**:247-249. Fig. 12.

PEACH (*Amygdalus persica*).

BROWN ROT (*Sclerotinia fructigena*).

Causes a spotting of the leaves, blight of the smaller twigs and a rot of the fruit. The fruit becomes shriveled up and covered with numerous brown pustules of powdery spores. These diseased fruits may fall to the ground or remain on the tree as "mummies" until spring. On these rotted fruits in the ground there may develop fleshy outgrowths on which the perfect spores are produced.

1. Plant the most resistant varieties. No variety seems to be immune but some are less injured than others.

2. Keep the trees well pruned and thin out the fruit.

3. Thruout the season pick and burn all diseased peaches.

4. In the fall gather and burn all rotted peaches on the ground or remaining on the trees.

5. Spray with 4-4-50 Bordeaux as follows:

Cordley, A. B.
1899 Brown Rot. Bul. Oregon Exp. Sta. **57**:1-15. Fig. 1-7.
Faurot, F. W.
1908 Brown Rot of the Peach. Rpt. Mo. State Bd. of Hort. **1907**:285-289.
Norton, J. B. S.
1902 Sclerotinia fructigena. Trans. Acad. Sci. St. Louis **12**:91-97. Pl. 18-21.
Quaintance, A. L.
1900 The Brown Rot of Peaches, Plums and Other Fruits (*Monilia fructigena* Persoon). Bul. Ga. Exp. Sta. **50**:233-269. Fig. 1-9.

LEAF CURL (*Exoascus deformans*).

The leaves become irregularly curled and swollen and covered with a whitish bloom. Parts or all of the leaf may become curled. The fungus is also frequently perennial in the small twigs which become swollen. Infection of leaves in the spring may take place by either (a) the growth of the perennial mycelium of the twig out thru the petiole into the leaf or (b) spore infection. The major part of the infection takes place by the second method.

1. Spray with lime sulfur or 2 pts. blue vitriol to 50 gallons water about 1 to 3 weeks before buds open.

2. Spray with 5-5-50 Bordeaux mixture just as buds begin to swell.

Atkinson, G. F.
1894 Leaf Curl and Plum Pockets. Bul. N. Y. Cornell Exp. Sta. **73**:319-355. Pl. 1-20.
Duggar, B. M.
1899 Peach Leaf-Curl and Notes on the Shot-Hole Effect of Peaches and Plums. Bul. N. Y. Cornell Exp. Sta. **164**:367-388. Fig. 64-72.
Murrill, W. A.
1900 The Prevention of Peach Leaf Curl. Bul. N. Y. Cornell Exp. Sta. **180**:319-334.
Pierce, N. B.
1900 Peach Leaf Curl, Its Nature and Treatment. Bul. Div. Veg. Phys. and Path. U. S. Dept. Agr. **20**:1-204. Pl. 1-30.

ROSETTE

1. Destruction of infected trees is the only method of control.

BAILEY, L. H.

1894 Peach Yellows. Bul. N. Y. Cornell Exp. Sta. **75**:393-408. Fig. 1-6.

SELBY, A. D.

1896 Peach Yellows. Bul. Ohio Exp. Sta. **72**:193-206. Fig. 1-5, Pl. 1.

1898 Peach Yellows. Bul. Ohio Exp. Sta. **92**:190-199. Fig. 4-5, Pl. 1-2.

SMITH, E. F.

1891 Additional Evidence on the Communicability of Peach Yellows and Peach Rosette. Bul. Div. Veg. Phys. and Path. **1**:1-65. Pl. 1-39.

1893 Experiments with Fertilizers for Prevention and Cure of Peach Yellows, 1889-92. Bul. Div. Veg. Phys. and Path. U. S. Dept. Agr. **4**:1-197. Pl. 1-33.

1894 Peach Yellows and Peach Rosette. Farmers' Bul. **17**:1-20. Fig. 1-7.

SCAB OR BLACK SPOT (*Cladosporium carpophilum*).

Brown or nearly black spots appear on the surface of the fruit; these spots may coalesce to a greater or less extent and if the disease is confined to one side of the fruit serious cracking may result.

1. Spray dormant trees with the self-boiled lime-sulfur wash.
2. Spray with 3-3-50 Bordeaux mixture—
   A. Before the blossoms open.
   B. Again after two or three weeks.

SELBY, A. D.

1904 Peach Diseases III. Studies in the Prevention of Leaf Curl and Scab. Bul. Ohio Exp. Sta. **148**.

YELLOWS.

Like the rosette the cause of this disease is as yet unknown.

PEAR (*Pyrus communis*).

FIRE BLIGHT OR PEAR BLIGHT (*Bacillus amylovorus*).

Follow the directions given under Apple Fire Blight and in addition:

1. Reduce the amount of nitrogenous fertilizers used and avoid forcing a rapid and succulent growth of young wood.
2. Plant the most resistant varieties.

Alwood, W. B.

1903 On the Occurrence and Treatment of Fire Blight in the Pear Orchard. Bul. Va. Exp. Sta. **135**:49-66. Fig. 16-20.

Chester, F. D.

1901 Notes on Pear Blight. Rpt. Del. Exp. Sta. **12**-1900: 38-43. Fig. 1-3.

1901 Pear Blight and Pear Canker. Bul. Del. Exp. Sta. **52**:1-8. Fig. 1-7.

Waite, M. B.

1896 The Cause and Prevention of Pear Blight. Yearbook U. S. Dept. Agr. **1895**:295-300.

SCAB (*Venturia pirina*).

The symptoms of this disease are the same as for apple scab, *q. v.* The perfect stage of the fungus develops on the old leaves while the imperfect stage causes spots on the leaves and scab of the fruit.

1. Plow under or clean up and destroy all dead leaves in the fall.
2. Spray late every winter with lime-sulfur-salt.
3. Spray with Bordeaux mixture as follows:
    - A. When the buds are slightly swollen. Use 8-10-50 Bordeaux.
    - B. When, about a week later, the petals begin to show. Use 5-5-50 Bordeaux.

Beach, S. A.

1894 Experiments in Preventing Pear Scab. Rpt. N. Y.

PLUM (*Prunus*).

BROWN ROT (*Sclerotinia fructingena*).

See Peach—Brown Rot.

CANKER.

The exact cause of the well-known cankers of plums and cherries has never been determined.

LEAF SPOT OR SHOT HOLE (*Cylindrosporium padi*).

(Consult Cherry—Leaf Spot or Shot Hole.)

POTATO (*Solanum tuberosum*).

DRY ROT (*Fusarium oxysporum*).

This rot attacks the tubers while still in the field. It gains entrance to the interior thru the stem end or thru small wounds in the skin of the potato. It may be detected first as a browning of a ring inside of the potato. Later this may spread and accompanying it the potato becomes hard and often dry and leathery or woody. If slightly diseased potatoes are stored in a warm place the rot will develop in the storage bin and ruin all of the potatoes in the bin. This rot may be prevented in the field to some extent by planting only healthy potatoes in soil that has not been infected. In the storage bin the rot may be held in check by the following measures:

1. Throw out all tubers showing any indications of disease.
2. Throw out all bruised and cut tubers.
3. Store in a cool dry place; the temperature should be about 40° F.

CLINTON, G. P.
1895 Dry End-Rot. Bul. Ill. Exp. Sta. **40**:139-140. Fig. 4.
SMITH, E. F. AND SWINGLE, D. B.
1904 The Dry Rot of Potatoes Due to Fusarium Oxysporum. Bul. Bur. Plant Ind. U. S. Dept. Agr. **55**:1-64. Pl. 1-8.

EARLY BLIGHT (*Alternaria solani*).

This disease appears about the time the plants are in bloom in the form of small grayish-brown spots which are later marked

2. Gather all the old "tops" and burn them to prevent the spores from wintering over.

(Consult the Bibliography of Potato—Late Blight and Rot.)

INTERNAL BROWN SPOT.

As the name indicates, this disease is characterized by the appearance of brown spots in the tuber. This is a rather obscure disease which probably has its origin in some physiological disturbance—at least no organism has yet been connected with it.

MORSE, W. J.
1907 Internal Brown Spot of the Tuber. Bul. Maine Exp. Sta. **149:** 318-321. Fig. 48.

LATE BLIGHT AND ROT (*Phytophthora infestans*).

The fungus causing this disease enters the leaves thru the stomates. From these stomates later emerge the threads on which the summer spores are produced. Not only are the leaves destroyed but the spores are washed down with the soil and cause the well-known rot of the tubers.

1. Spray with 5-5-50 Bordeaux as follows:
   - A. When the plants are 5-6 inches high.
   - B. Repeat every 10-14 days—making 5-7 applications in all.
   - C. Use from 50-100 gallons to the acre at each application.

CLINTON, G. P.
1905 Downy Mildew, or Blight, *Phytophthora infestans* (Mont.) DeBy., of Potatoes. Rpt. Conn. Exp. Sta. **1904**: 363-384. Pl. 32-37.

JORDAN, W. H., STEWART, F. C. AND EUSTACE, H. J.
1905 Effect of Certain Arsenites on Potato Foliage. Bul. N. Y. Geneva Exp. Sta. **267**:263-284. Pl. 1-2, fig. 1.

STEWART, F. C.
1896 Potato Diseases on Long Island in the Season of 1895. Bul. N. Y. Geneva Exp. Sta. **101**:69-86.
1897 Spraying Potatoes on Long Island in the Season of 1896. Bul. N. Y. Geneva Exp. Sta. **123**:233-259. Pl. 1, fig. 1.

STEWART, F. C., EUSTACE, H. J., FRENCH, G. T. AND SIRRINE, F. A.
1907 Potato Spraying Experiments in 1906. Bul. N. Y. Geneva Exp. Sta. **290**:237-321. Pl. 1-2.

Stewart, F. C., **Eustace**, H. J. and **Sirrine**, F. A.
1902 Potato Spraying Experiments in 1902. Bul. N. Y. Geneva Exp. Sta. **221**:235-263.
1903 Potato Spraying Experiments in 1903. Bul. N. Y. Geneva Exp. Sta. **241**:251-292. Pl. 1-12.
1905 Potato Spraying Experiments in 1904. Bul. N. Y. Geneva Exp. Sta. **264**:95-204. Pl. 1-16.
1906 Potato Spraying Experiments in 1906. Bul. N. Y. Geneva Exp. Sta. **279**:153-229. Pl. 1-5.

SCAB (*Oospora scabies*).

The common name well indicates the symptoms of this well-known disease. Other causes than the fungus named may cause scab and the whole question needs further study.

1. If the soil is badly infested rotation with other crops for several years may be necessary.

2. Plant only clean potatoes.

3. Treat the "seed" potatoes by soaking for 1½ hours in either:

A. Solution of 1 ounce of corrosive sublimate in 7 gallons of water.

B. Solution of 1 pint of formalin to 30 gallons of water.

Arthur. J. C.
1897 Formalin for Prevention of Potato Scab. Bul. Ind. Exp. Sta. **65**:17-36. Pl. 1-2.

Bolley, H. L.
1890 Potato Scab: A Bacterial Disease. Agr. Sci. **4**:243-256, 277-287. Pl. 3-4.
1891 Potato Scab and Possibilities of Prevention. Bul. N. Dak. Exp. Sta. **4**:3-17. Pl. 1-2, fig. 1-4.

Jones, L. R. and **Edson**, A. W.
1901 Potato Scab and Its Prevention. Bul. Vt. Exp. Sta. **85**:109-120. Fig. 1-2.

Morse, W. J.
1907 The Prevention of Potato Scab. Bul. Maine Exp. Sta. **141**:81-92.

SOFT ROT (*Bacillus solanacearum*).

This rot is due to bacterial action. The rotting potatoes become soft, wet, soggy, and have an offensive odor. This rot often follows or accompanies the dry rot. It gains entrance thru cracks in the tuber due to the dry rot or to bruises.

1. Discard all cut and bruised potatoes.

2. Store in a cool dry cellar. The temperature of the cellar should be kept at about 40° F.

Sᴍɪᴛʜ, E. F.
1896 A Bacterial Disease of the Tomato, Eggplant, and Irish Potato (*Bacillus solanacearum* n. sp.). Bul. Div. Veg. Phys. and Path. U. S. Dept. Agr. **12**:1-26. Pl. 1-2.

SPROUTING.

Frequently late in the spring considerable loss is sustained by the potatoes sprouting.

1. Keep the potatoes dark, dry and at a temperature of about 40° F.

RASPBERRY (*Rubus sp.*).

ANTHRACNOSE (*Gloeosporium venetum*).

(Consult Blackberry Anthracnose).

CROWN GALL.

(Consult Blackberry Crown Gall).

RUST (*Gymnoconia interstitialis*).

(Consult Blackberry Rust).

ROSE (*Rosa*).

BLACK SPOT (*Actinonema rosae*).

Irregular black patches of the fungus mycelium appear on the leaves; in severe attacks these patches may cover the entire leaf.

1. Spray outdoor roses with 5-5-50 Bordeaux as follows:
   A. When first spots appear on the leaves.
   B. Repeat three times at intervals of 8-10 days.

2. Spray greenhouse roses with ammoniacal copper carbonate once a week until the disease is checked.

MILDEW (*Sphaerotheca humuli* and *pannosa*).

The leaves, buds and young shoots become covered with a

2. Out-of-door roses should be treated in *either* of the following ways:

   A. Spray 2-3 times with solution of potassium sulfid (1 ounce to 30 gallons of water) every 7-10 days.
   B. Dust 2-3 times with sulfur every 7-10 days.

RYE (*Secale cereale*).

ERGOT (*Claviceps purpurea*).

This fungus disease attacks the ovary and transforms it into a purplish-black mass about half an inch long and an eighth of an inch in diameter. This mass is known as "ergot" and is a storage organ of the fungus. The spring following its formation this "ergot" produces a number of little stalks which bear the spores. These infect the ovaries in the heads of rye and thus the fungus is perpetuated from year to year. The fungus also forms summer spores which spread the fungus rapidly during the summer. This disease also occurs on many of the wild grasses such as the wild rye grasses, wild wheat grasses, Colorado blue stem, where it becomes a source of danger in feeding. It also occurs on some of the cultivated grasses such as brome grasses, redtop, and some others.

1. The grass should be mown before the heads are developed so that no ergot will be formed.
2. Patches that are badly affected should be burned over to destroy the ergot as the grass is unfit for feed.
3. Grasses around the rye fields, known to be diseased, should be kept mowed down.
4. Some authors recommend the treating of seed known to contain ergot with the smut treatment.
5. In saving seed the ergot should be screened out.

Heald, F. D. and Peters, A. T.
1906 Ergot and Ergotism. Press Bul. Nebr. Exp. Sta. **23**:1-7. Fig. 1-3.
McCarthy, G.
1891 Plant Diseases and How to Combat Them. Bul. N. Car. Exp. Sta. **76**:20.
Williams, T. O.
1893 Some Plants Injurious to Stock. Bul. S. Dak. Exp. Sta. **33**:40-43.

ORANGE LEAF RUST (*Puccinia rubigo-vera secalis*).

This rust very closely resembles the leaf rust of wheat. The leaf rust of wheat however does not grow on rye nor vice versa. The leaves early show lines and patches of powdery orange red spores. These patches spread until the whole leaf may be covered with the red powder. Later there are formed beneath the epidermis in small black lines the teliaspores. This rust occurs also on some of the wild grasses.

1. Keep down the native grasses around the field.
2. Destroy the volunteer rye that comes up before the regular sowing.
3. Sow the seed in such a manner as to give all the plants an even start.
4. Sow varieties known to be rust resistant.

(Consult Bibliography of Barley—Black Rust.)

SORGHUM, KAFIR CORN, BROOM CORN (*Sorghum vulgare*).

HEAD SMUT (*Sphacelotheca reiliana*).

This smut destroys the whole head. At harvest time the heads fail to develop but at the point where they should be there is formed a black mass of spores much resembling the smut of corn.

1. Treatment with formalin, hot water or bluestone method is of no value.
2. Observe the following suggestions:
   - A. Secure seed from fields known to be free from head smut.
   - B. Be sure that this seed has not been threshed by machinery that was used to thresh smutted sorghum.
   - C. After you have once secured clean seed, raise your own seed and use your own machinery in taking care of it.

(Consult the Bibliography of Sorghum—Kernel Smut.)

KERNEL SMUT (*Sphacelotheca sorghi*).

At harvest time the heads contain no seed but are made up of a black powdery mass of spores which is so well protected by the them adhere to the seed. These are sown with the seed and the plant becomes infected before it reaches the surface of the soil.

1. Secure seed free from smut.

2. Grow your own seed and harvest and thresh it with your own machinery.

3. If you must plant smutted seed treat it by any of the methods given for barley smut.

CLINTON, G. P.
1897 Broom Corn Smut. Bul. Ill. Agr. Exp. Sta. **47**.
FREEMAN, M. E. AND UMBERGER, H. J. C.
1908 The Smuts of Sorghum. Circ. Bur. Plant Ind. U. S. **8**.

STRAWBERRY (*Fragaria chilaeensis*).

LEAF SPOT, RUST OR LEAF BLIGHT (*Sphaerella fragariae*).

Light brown spots with purplish-red margins appear on the leaves, which may die as a result.

1. When setting out plants be certain to remove all diseased leaves before taking the plants to the new field.

2. Cut down the plants and burn the beds after the fruit is gathered.

3. Spray with 5-5-50 Bordeaux as follows:

   A. Soon after growth begins.

   B. Repeat three or four times at intervals of 10-14 days.

4. Plant the most resistant varieties.

BAILEY, L. H.
1894 Leaf Blight. Bul. N. Y. Cornell Exp. Sta. **79**:600-604. Fig. 1.

TOMATO (*Lycopersicum esculentum*).

ROTS.

There are several distinct sorts of rots of tomatoes due to different organisms. These can often be distinguished with certainty by a specialist only.

SMITH, ELIZABETH H.
1907 The Blossom End Rot of Tomatoes. Technical Bul. Mass. Exp. Sta. **3**:1-19. Fig. 1-6.

WHEAT (*Triticum vulgare*).

BLACK RUST OR STEM RUST (*Puccinia graminis tritici*).

This rust is very common in years having a good rainfall and frequently destroys practically the entire crop. It seems to be more severe on spring wheat than on winter wheat where both are grown in the same community. Among the spring wheats the durum or macaroni wheats seem to be least affected. It first appears as reddish lines on the leaves and stems. These increase in number and size, often running together to form large streaks which later become dark brown or nearly black. In both stages the lines are frequently bordered by the ruptured epidermis. In the fall the volunteer wheat and some of the early sown wheat may show the red rust. It is probable that in this region the rust must winter over in the winter wheat and some of the wild grasses. From this the rust starts again in the spring. In some localities early in the spring the barberry hedges are affected with a cluster cup which is another form of this rust. Where this occurs the wheat is always much more severely rusted in the vicinity of the hedge.

1. Cut down all barberry hedges.
2. Do not try to grow both winter wheat and spring wheat in the same section.
3. Destroy the volunteer wheat.
4. Sow in such a way as to give all plants an even chance.
5. Other things being equal, early wheats will suffer least.
6. Sow rust-resistant varieties.
7. Keep down the wild grasses, especially wild barley and wild wheat.
8. Carefully grade the seed, sowing only grain of perfect form and weight.
9. Properly till and drain the soil.
10. Practice the most desirable crop rotation.

(Consult the Bibliography of Barley—Black Rust).

ORANGE LEAF RUST (*Puccinia rubigo-vera tritici*).

This rust is very common on the wheat. It becomes apparent somewhat earlier than the black stem rust and is confined principally to the leaves. The rust first appears as an orange red powder on the leaves. This gradually spreads until nearly the whole leaf is covered. This is the summer stage. Later this is followed by the winter spore stage consisting of small dark lines and patches formed under the epidermis of the leaf. The uredo, or summer spores, remain alive for some time even after the wheat is harvested and infect the volunteer wheat and later the fall sown wheat. Here it lives over the winter in the tissues of the wheat plant and is ready to start the infection the following spring. The cluster cup stage of this rust is not known in this country. This rust also occurs on some of the wild grasses, especially on the wild wheat grasses. These help to carry the fungus from harvest time till fall and during the winter. The plan of careful cultivation and seed selection recommended for the black or stem rust is also of service here. The campaign against both forms of rust may be carried on at the same time.

(Consult the Bibliography of Barley—Black Rust).

LOOSE SMUT (*Ustilago tritici*).

At harvest time the affected heads contain no seed but appear as black powdery masses of spores. In this region the winds often blow the spores away leaving only the naked central stem of the head and a few bracts or scales.

Infection takes place at flowering time and the fungus grows into the embryo of the developing seed. From such an infected seed a smutted plant will develop the following year. This smut may be prevented by the Jensen modified hot-water treatment:

A. Soak the seed for 5 hours in cold water.
B. Place in water kept at 130° F. for about 10 minutes.
C. Spread out on a clean floor or canvas and allow to dry.

NOTE: This treatment is very severe and some of the wheat grains will be killed. A fourth to a half more seed should be sown than under ordinary conditions, i. e., instead of sowing two bushels per acre two and a half to three should be sown.

(Consult the Bibliography of Barley–Loose Smut..)

STINKING SMUT OR BUNT (*Tilletia foetans*).

At harvest the affected heads contain no seed but in their places are false berries filled with black smut masses having a disagreeable odor. In threshing, the false berries are broken open and the smut spores scattered; some of them adhere to the grains of wheat. The smut spores are sown with the grain and the wheat seedling becomes infected before it appears above the soil. This smut does much damage not only in reducing the yield but wheat badly smutted loses grade in the market as it is unfit for milling purposes. This smut may be prevented by any one of the methods given for barley smuts and oat smuts. For small amounts the Modified Formalin Method is easiest to apply. For large amounts the chimney method cited under oat smut is most advantageous as it is very rapid.

HEALD, F. D.
1908 Bunt or Stinking Smut of Wheat. Press Bul. Nebr. Exp. Sta. **28**. Reprinted as Bul. Nebr. Insect Pest and Plant Disease Bureau **2**:1-8. Fig. 1-3.
KELLERMAN, W. A. AND SWINGLE, W. T.
1890 Preliminary Experiments with Fungicides for Stinking Smut of Wheat. Bul. Kans. Agr. Exp. Sta. **12**.
REED, J.
1903 Treatment of Stinking Smut in Wheat. Bul. Col. Agr. Exp. Sta. **79**.

INHERITANCE OF COLOR IN THE SEEDS OF THE COMMON BEAN, *Phaseolus vulgaris*.

By R. A. Emerson.

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INHERITANCE OF COLOR IN THE SEEDS OF THE COMMON BEAN, *Phaseolus vulgaris.*

BY R. A. EMERSON.

INTRODUCTION.

Something over ten years ago I began crossing races of beans with the idea of determining whether there are any definite principles controlling inheritance in crossbred plants. During the first few years, the work was carried on as rapidly as my limited time would permit, but this first work was done in entire ignorance of the results secured by Gregor Mendel many years before and brought to light soon after my hybridization experiments were begun. It should go without saying that all my later results have been studied in the light of Mendelian principles.

During the ten years while this work was being carried on, two minor papers giving some of the results secured were published.[1] Soon after the publication of the second of these papers, the work was seriously interrupted by other duties and was all but abandoned for two or three years. Recently by transferring much of the work of teaching to assistants and thru the help of the Adams fund, I have been enabled to take up the work on a much more comprehensive scale than ever before. During the two or three years when little time could be devoted to the work, considerable material accumulated which could not then be studied. A large part of this material was accidentally destroyed without any record having been made of it. What remained has recently been worked over and records of it have been made. These and the records previously made have been brought together to serve as a basis for the more extensive work now being undertaken.

Such of these records as have to do with color inheritance are presented here. Altho many of them are fragmentary, it is be-

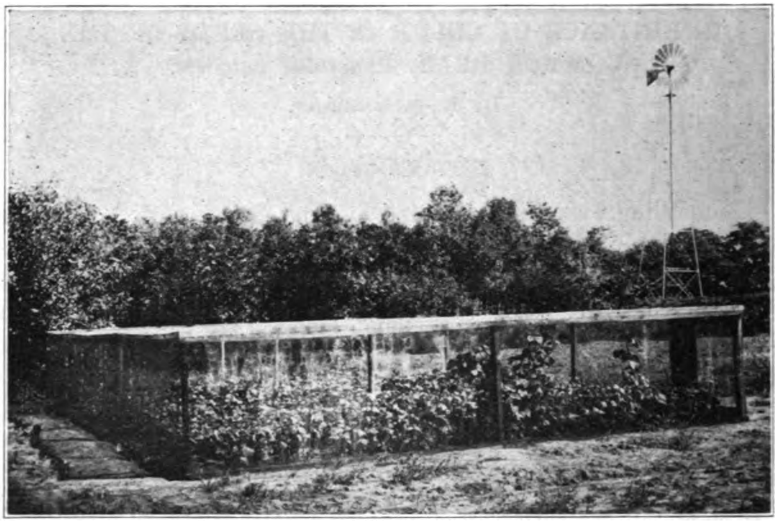

Fig. 1. A frame covered with wire cloth to protect plants from cross-pollination by insects.

The records here reported were made from plants that were carefully guarded against accidental cross-pollination by insects. The methods used to accomplish this during the earlier part of the work were described in my previous papers (*loc. cit.*). During two seasons, all the plants were grown close together under a frame covered with wire cloth (fig. 1). Since then I have invariably used individual covers of cheese-cloth or light muslin supported by a frame of heavy wire (figs. 2 and 3). The crossing of plants has always been done in a greenhouse. Usually the work has been performed during the winter when there were no bees about, in which case the flowers have not been covered.

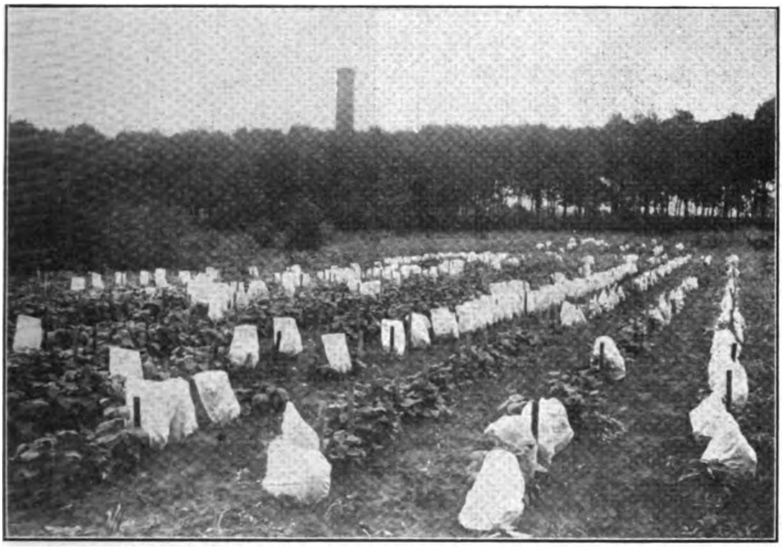

Fig. 2. Garden of hybrid beans illustrating the use of individual plant covers to prevent crossing by insects.

Blue Pod—Blue Pod Butter.
Burpee Stringless—Burpee's Stringless Green Pod.
Challenge Black—Challenge Black Wax.
China—China Red Eye.
Currie—Currie's Rustproof Golden Wax.
Davis—Davis Wax, Davis White Wax.
Dwarf Horticultural—Dwarf Horticultural.
German Black—German Black Wax Bush.
Giant Stringless—Giant Stringless Green Pod.
Golden Wax—Ferry's Golden Wax.
Jones Stringless—Jones Stringless Wax.
July—Tall July Runner Pole.
Keeney Rustless—Keeney's Rustless Golden Wax.
Leopard—Leopard Wax.
Marrow—White Marrow Field.
Mohawk—Early Mohawk.
Navy—Navy Pea Field, White Navy.
Paris—Marvel of Paris.

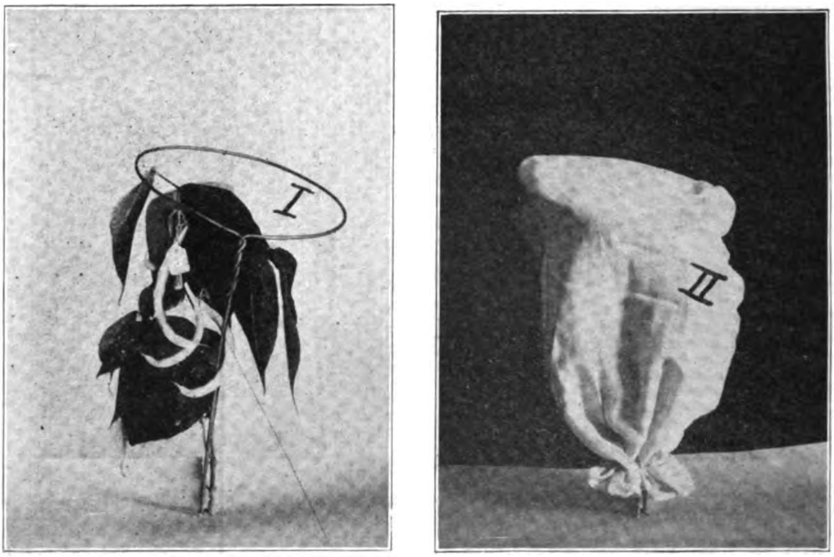

Fig. 3. Details of the individual plant cover. I. Plant with wire support in place. II. Lightmuslin sack drawn over the support and tied about the wire and the stem of the plant.

Prolific Black—Prolific Black Wax.
Round Pod Kidney—Round Pod Kidney Wax.
Scarlet Flageolet—Scarlet Flageolet Wax.
Tennessee—Tennessee Green Pod.
Ultra—Ne Plus Ultra.
Wardwell—Wardwell's Kidney Wax.
Warwick—Early Warwick.
Yellow Eye—Improved Yellow Eye.

PRESENCE AND ABSENCE OF PIGMENT.

In all cases that have come under my observation, the presence of pigment in bean seeds has been dominant to the absence of accord with Mendelian expectation. The exceptions have been due doubtless to the small numbers dealt with in certain cases.

Crosses made by the writer and his students illustrating the inheritance of pigment in bean seeds are as follows, the first named race of each pair being the non-pigmented one: Davis-Challenge Black, Davis-Blue Pod, Davis-Ultra, Davis-Scarlet Flageolet, Davis-Keeney Rustless, Davis-Wardwell, July-Warwick, Navy-Ultra, Navy-Paris, Navy-Challenge Black, Navy-Wardwell, Navy-Warwick, Marrow-Ultra, Marrow-Paris, Jones Stringless-Golden Wax, Jones Stringless-Hybrid 57, Jones Stringless-Burpee Stringless, Hybrid 102-German Black. Of the F_1 individuals of the above crosses, 133 were pigmented and none without pigment. Of the F_2 individuals from some of the above crosses, 280 were pigmented and 111 were white, a small excess of whites over the one-fourth expected (see page 98). Twenty-five F_2 whites produced 276 F_3 plants all with white seeds. In two cases these white recessives were carried to the F_4 generation and in one case to F_5 without the appearance of pigmented forms. Seven pigmented F_2 individuals produced 94 F_3 plants all with pigmented seeds, while 38 other pigmented F_2 individuals yielded in F_3 191 pigmented and 70 white individuals, or something more than 25 per cent white.

TOTAL AND PARTIAL PIGMENTATION.

Pigmented beans have pigment either over the entire surface of their seeds or over only a part of the surface. In the latter case, the pigment usually appears around the "eye" of the seed, leaving the "back" without pigment. The pigmented area in "eyed" beans varies greatly in extent in different races and sometimes considerably within a race. In some races it is reduced to a very small spot about the hilum, while in others it sometimes extends over as much as four-fifths of the surface of the seed.

When a totally pigmented bean has been crossed with an eyed bean, total pigmentation has occurred in F_1 to the exclusion of the eyed type. In F_2 the eyed form has again appeared and in later generations has bred true. Some of the totally pigmented F_2 individuals have bred true while others, on being self-fertilized, have yielded both totally pigmented and eyed forms. The detailed results of these crosses are shown in the following tables.

TABLE I.—*Results of crossing totally pigmented with partially pigmented beans.*

Parentage	Number of plants.			
	F_1		F_2	
	Totally pigmented.	Partially pigmented.	Totally pigmented.	Partially pigmented.
Currie *T.*[2] × Golden Wax *E.*[2]	2	0	29	13
Wardwell *E.* × Challenge Black *T.*	1	0	27	10
Golden Wax *E.* × Mohawk *T.*	2	0	8	7
Yellow Eye *E.* × Dwarf Horticultural *T.*	1	0	..	..
Total	**6**	**0**	**64**	**30**

[2] "*T.*" after the name of a race indicates that the race has totally pigmented seeds while "*E.*" indicates partial (eyed) pigmentation.

TABLE II.—*Total and partial pigmentation in F_3.*

Parentage.	F_2		Number plants in F_3	
	No. plants.	Pigmentation.	Totally pigmented.	Partially pigmented.
Currie × Golden Wax	7	Partial	0	19
Wardwell × Challenge Black	8	Partial	0	35
Golden Wax × Mohawk	4	Partial	0	28
Total	**19**	Partial	**0**	**82**
Currie × Golden Wax	16	Total	34	0
Wardwell × Challenge Black	16	Total	124	0
Golden Wax × Mohawk	3	Total	6	0
Total	**35**	Total	**164**	**0**
Currie × Golden Wax	5	Total	16	6
Wardwell × Challenge Black	9	Total	54	16
Golden Wax × Mohawk	2	Total	2	3
Total	**16**	Total	**72**	**25**

The totally pigmented individuals in F, were fewer than ex-is due to chance on account of the small number of F_2 plants secured or whether it has some real significance is not apparent. In F_3, from heterozygous F_2 individuals, there was a slight excess of plants with partially pigmented seeds, the ratio of the two types being nearly 2.9: 1.

Of the totally pigmented F_2 individuals, at least 16 are seen from the table to have been heterozygous with respect to total pigmentation. It cannot be said that all of the 35 F_2 individuals that bred true to total pigmentation were homozygous with respect to that character, for in some cases the offspring were too few to allow of certainty in classifying the parents. This is true of all F_2 individuals of Currie × Golden Wax and Golden Wax × Mohawk and of some of those of Wardwell × Challenge Black. Some of the F_2 plants of the latter cross, however, were almost certainly homozygous. One of them yielded 23 totally pigmented individuals in F_3 and no partially pigmented ones. Similarly, the results indicate, tho the numbers are too few for proof in all cases, that the partially pigmented F_2 plants were homozygous with respect to pigmentation. The results in later generations point even more clearly to the same conclusions. From 4 F_3 partially pigmented individuals there were grown 36 F_4 plants with eyed (partially pigmented) seeds and 3 of these yielded 65 eyed individuals in F_5, 38 of which in turn produced 750 F_6 individuals of the eyed type. In all these generations not a single totally pigmented seed was produced from eyed parents.

TOTAL PIGMENTATION LATENT IN WHITE BEANS.

In several crosses of partially pigmented (eyed) beans with non-pigmented (white) beans, the F_1 plants have produced totally pigmented seeds. This fact was noted and illustrated in my first paper on bean hybrids[3] but without any appreciation of its significance. Seven such crosses have been made, the results of which are shown in the following table.

TABLE III.—*Results of crossing partially pigmented with non-pigmented beans.*

Parentage	Number of plants.					
	F_1			F_2		
	Totally pigmented.	Partially pigmented.	Non-pigmented.	Totally pigmented.	Partially pigmented.	Non-pigmented.
Navy *W.*[4] × Wardwell *E.*	1	0	0	3	1	3
Wardwell *E.* × Navy *W*	2	0	0	2	1	1
Wardwell *E.* × Davis *W*	1	0	0	1	1	3
Keeney Rustless *E.* × Davis *W*	1	0	0	2	1	2
Jones Stringless *W.* × Golden Wax *E*	1	0	0	6	6	7
Jones Stringless *W.* × Hybrid 57 *E*	2	0	0	..	..	..
Hybrid 57 *E.* × Jones Stringless *W*	4	0	0	..	..	..
Total	12	0	0	14	10	16

[4] "*W.*" indicates a non-pigmented (white) race.

Ten F_2 white-seeded plants produced 50 plants in F_3, all of which had white seeds. The progeny (in small numbers) of two of these F_3 plants was tested to F_5 without the production of a single pigmented seed, indicating again the homozygous nature of extracted whites with respect to the absence of pigment. From 7 F_2 plants with eyed seeds there were grown 47 F_3 plants, 34 eyed and 13 white. This shows that they were heterogametous toward the presence of pigment and apparently homogametous with respect to the absence of total pigmentation. Besides these, one F_2 eyed plant produced 5 partially pigmented and no white or totally pigmented individuals in F_3. Its progeny was too few to more than indicate its possible homogametous nature with regard to the presence of pigment and the absence of total pigmentation. One totally pigmented F_2 plant yielded in F_3 7 totally pigmented, 3 eyed, and 5 white individuals, showing it to have been heterogametous with regard to both the presence of pigment and of total pigmentation. Two totally pigmented F_2 plants yielded a progeny of 17 F_3 plants, 9 totally pigmented, 8 white, and none eyed, thus having been apparently homogametous toward total pigmentation tho heterogametous to the presence of pigment. One totally pigmented F_2 plant gave 8 totally pigmented plants in F_3, suggesting its possible homogametous nature toward both the characters concerned. Another totally pigmented F_2 plant produced 3 totally pigmented, one eyed, and no white individuals in F_3, enough to show its heterogametous nature toward total pigmentation, but not enough to prove it to be homogametous toward the presence of pigment.

The non-pigmented parents, Davis, Jones Stringless, and Navy, apparently have a character such that, when pigment is present, it extends over the entire surface of the seed. This character cannot be present in the partially pigmented parents, Keeney Rustless, Wardwell, Golden Wax, and Hybrid 57, else those races would be totally pigmented instead of eyed. The character is latent (invisible) in the white parents simply because it cannot be seen except in the presence of pigment.

FACTORS[5] CONCERNED IN PIGMENTATION.

I have here chosen to express the relation of the totally pigmented, partially pigmented, and non-pigmented types of bean seeds, as dependent upon two distinct factors: first, presence of pigment, *P*, allelomorphic to the absence[6] of pigment, *p*; and, second, the presence or absence of a factor for total pigmentation, *T* or *t*. Under this assumption, four gametic formulas are possible, namely,

(1) *PT*—total pigmentation.
(2) *Pt*—partial pigmentation.
(3) *pT*—no pigmentation, total pigmentation latent.
(4) *pt*—no pigmentation, either visible or latent.

No white bean has yet been found by me to have formula 4. Davis, Navy, and Jones Stringless, the only white races that have been crossed with eyed races, have yielded totally pigmented offspring in F_1 from such crosses, thus indicating formula 3 for them. Several white races, when crossed with totally pigmented races, have yielded in F_1 only totally pigmented individuals and in F_2 totally pigmented and white individuals and no partially pigmented ones. If either of the white races tested had formula 4, some of the F_2 plants should have produced eyed seeds. The details of the crosses are shown in the following table:

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[5] The term "factor," as here used, means simply one of the elements that have to do in causing a particular character to appear.

[6] I here admit my belief in the hypothesis that a factor may be "entirely" *absent* from an organism. If the pigmented and non-pigmented conditions of bean seeds are due to "polarity of expression" in the soma (Cook), it is inconceivable to me that the gametes are not similarly "polarized." I am

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not unmindful of the possibility that two negatively polarized germ cells might on uniting give the same visible result that might be secured by the union of two gametes from which a particular factor was absent, and similarly that positive polarization might give the same result as the presence of a particular factor. If we adopt the "polarization" hypothesis, we must assume that, generation after generation, the gametes, in the case of extracted recessives, are all negatively polarized, in the case of extracted dominants, all positively polarized, and in case of heterozygotes, part negatively and part positively polarized. Or we may express this same assumption in terms of "alternate states of stability" (Morgan), in which case, making the necessary changes in phraseology, one "condition of equilibrium" must be maintained permanently in the gametes of extracted recessives and the other "condition" in the gametes of extracted dominants, while each condition occurs in one half of the gametes of heterozygotes. Again changing our words without changing our meaning, we may say that a factor might be present in all germ cells, but be "inactive" in some, "active" in others. Here again the factor must remain permanently inactive in some cases (recessives), permanently active in other cases (pure dominants), and alternately active and inactive in other cases (heretozygotes). What was pointed out by Morgan concerning the "factor hypothesis" (Amer. Breeders' Assoc. 5:365,]1909]) is equally true of the other hypotheses noted above, as indeed of all hypotheses! They all explain the facts excellently "because the explanation was invented to explain them." In short, we must recognize that any explanation is hypothetical. I choose the presence-and-absence hypothesis because it appeals to me as the most reasonable "explanation" of the results I have to report.

TABLE IV.—*Results of crossing totally pigmented with non-pigmented beans.*

Parentage.	Number of plants.					
	F_1			F_2		
	Totally pigmented.	Partially pigmented.	Non-pigmented.	Totally pigmented.	Partially pigmented.	Non-pigmented.
Davis *W.* × Challenge Black *T.*	3	0	0	23	0	6
Challenge Black *T.* × Davis *W.*	1	0	0	4	0	1
Davis *W.* × Blue Pod *T.*	3	0	0	5	0	2
Blue Pod *T.* × Davis *W.*	4	0	0	17	0	10
Scarlet Flageolet *T.* × Davis *W.*	2	0	0	7	0	4
Davis *W.* × Ultra *T.*	5	0	0	41	0	20
Marrow *W.* × Ultra *T.*	8	0	0	15	0	3
Ultra *T.* × Marrow *W.*	14	0	0	14	0	12
Marrow *W.* × Paris *T.*	30	0	0	39	0	13
Navy *W.* × Paris *T.*	17	0	0	31	0	8
Paris *T.* × Navy *W.*	6	0	0	21	0	4
Navy *W.* × Challenge Black *T.*	3	0	0	20	0	8
Ultra *T.* × Navy *W.*	13	0	0	19	0	4
Navy *W.* × Warwick *T.*	1	0	0	..	..	..
July *W.* × Warwick *T.*	1	0	0	..	..	..
Jones Stringless *W.* × Burpee Stringless *T.*	2	0	0	..	..	..
Hybrid 102 *W.* × German Black *T.*	7	0	0	..	..	..
German Black *T.* × Hybrid 102 *W.*	1	0	0	..	..	..
Total	**121**	**0**	**0**	**256**	**0**	**95**

The table shows conclusively enough that the white races, Davis, Marrow, and Navy, do not have formula 4 (*pt*). The results from the F_3 records, however, add still more evidence in the case of Davis and Navy. The Davis-Blue Pod, Davis-Scarlet Flageolet, and Navy-Challenge Black crosses yielded, in F_3, from 15 F_2 white-seeded plants, 226 white-seeded ones; from 6 totally pigmented F_2 individuals, 86 totally pigmented ones; and from 24 other totally pigmented F_2 plants, 129 totally pigmented and 44 white ones. No eyed beans were produced. The white races July, Jones Stringless, and Hybrid 102 were not carried to F_2, but Jones Stringless, as well as Davis and Navy, has already been shown to have total pigmentation latent by the production of totally pigmented offspring in F_1 from a cross with an eyed race.

It is regretted that the race known as Hybrid 102 was not tested further. It was produced from a cross of Davis with Keeney Rustless, the latter an eyed race. From this cross one-third of the extracted whites should have had the formula *pt*, i. e., white without total pigmentation latent. If among the standard commercial races of beans no white ones are found without total pigmentation latent, it should be easy to produce such a race by crossing any white race with any eyed race. The white-seeded F_2 offspring of such a cross can be tested for latency of total pigmentation by crossing them with any eyed race. Or, without testing, one may feel sure that all white-seeded F_3 offspring of eyed F_2 plants from an eyed-white cross will not have latent the factor for total pigmentation. A white race without latent total pigmentation would be valuable for use in determining any type of pigmentation that may, possibly, be hypostatic[7] to total pigmentation in totally pigmented races (see formula 1, next paragraph).

It is possible, of course, that there are three factors concerned in determining the extent of pigmentation, namely, *P* or *p*, *T* or *t*, and *E* or *e*, the last named pair representing the presence or absence of partial (eyed) pigmentation. In this case there would be eight possible combinations of characters, as follows: (1) *PTE*, (2) *PTe*, (3) *PtE*, (4) *Pte*, (5) *pTE*, (6) *pTe*, (7) *ptE*, (8) *pte*. Totally pigmented beans would then be represented by formula 1[8] or 2, eyed beans by formula 3, and white beans by formula 4, 5, 6, 7, or 8. No totally pigmented race has yet been shown to have formula 2. If there is such a bean, on being crossed with an eyed one (formula 3) it should yield in F_2 about 6 per cent of white-seeded plants. No white-seeded plants have yet been obtained from crosses of totally pigmented with eyed beans. I have made only four such crosses, however, and only three of these have yielded F_2 progeny (see Table I). If there exists a factor, *E*, for partial pigmentation, it should be possible not only to produce a white bean by crossing two pigmented ones but also to produce a pigmented bean by crossing two white ones (formula 4 crossed by 5, 6, or 7). No such result has been obtained, but only a few such crosses have been made, namely Navy-Marrow, Navy-U. S. 2070,

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[7] Bateson, W. Science, n. s., **26**: 653.

[8] *E*, being hypostatic to *T*, is not visible when *T* is present

July-U. S. 2070, and Jones Stringless-Hybrid 102. Such a result would be analogous to the production of a purple sweet pea by crossing two white types.[9] Even tho no such results are ever secured, the factor *E* may still exist. If it were present in all beans, only formulas 1, 3, 5, and 7, of those given above, would be possible. Crossing the various types would then give the same results as if only the two factors *P* and *T* existed, as at first assumed in this paper.

It may even be possible that there are separate factors for different extents of eyed pigmentation, say *E,' E,''* etc. Races exist, and breed true within narrow limits of fluctuation, in which the eye pigmentation is reduced to a very small spot about the hilum (Round Pod Kidney). In other cases the eye pigment extends over a third or more of the entire surface of the seed (Yellow Eye, China). In still others there is marked variation in the extent of the eye pigmentation (Golden Wax, Wardwell). Little attention has been given the matter as yet, but one of my early crosses (Golden Wax × Mohawk) gives some little support to the idea that large-eyed or medium-eyed beans may produce small-eyed ones, while the reverse of this is not to be expected.[10]

Any suggestion, looking to the explanation of the relation of total to partial pigmentation, that is based upon the assumption of two factors, one for pigmentation about the eye and the other for pigmentation of the back of the bean, is to be dismissed at once. True, pigment is present in or absent from different parts of various plants and animals. Maize has pigment in the endosperm and absent from the pericarp, or the reverse, or pigment is present in both these parts or absent from both. But this has to do with distinct body regions. There is no definite line between the dorsal and ventral parts of a bean seed. It is simply a matter of whether the pigment extends over the entire surface of the seed or only over a part (large or small part) of it. In case of partial pigmentation the "eye" is always pigmented. I have never seen a bean with the back pigmented and the eye white.

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[9] **Bateson, W.** Proc. Inter. Conference on Plant Breeding and Hybridization Hort. Soc. N. Y. 1: 5 (1902).

[10] Ann. Rpt. Nebr. Agr. Expt. Sta. 16, Pl. II (1902).

Eyed pigmentation in beans is apparently more nearly analogous to the pigment centers in spotted mice and guinea pigs[11] than to pigmented regions in maize, there being only a single pigment center in beans instead of ten (five pairs) as in mice and guinea pigs.[12] The eyed condition in beans is perhaps even more nearly comparable to the hooded pattern in rats.[13] The different pigment centers in guinea pigs often exhibit different pigments, as red in one and black in another,[14] just as different body regions in fowls do,[15] while in beans the eye is never of one self-color and the back of another. Whether the extent of the pigment in eyed beans is amenable to selection as in the cases of rats[16] has not been determined.

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[11] Allen, G. M. Proc. Amer. Acad. Arts and Sci., 40: 112-114.

[12] It is possible that there are several pigment centers, instead of one, in all eyed beans. The pigment spot is usually bilaterally symmetrical. It is commonly much broader about the chalaza than at the opposite end of the hilum. When the pigment is greatly reduced, it often fails to extend entirely around the hilum. In this case there are usually two spots, one about the chalaza and one about the micropyle. The former is usually more or less rounded in outline, tho sometimes the two halves extend outward and backward like two wings while the latter is usually a comparatively long narrow stripe extending from near the hilum lengthwise of the seed in a direction opposite to that of the chalaza. Rarely this stripe is wanting, or its place is taken by a very small spot close to the micropyle. Sometimes, even, the small micropyle spot and the stripe are both present but separated by a very small non-pigmented area. In case of large eyes these pigment patches coalesce. Sometimes the margin of the eye-spot is a very definite, nearly straight, line (Yellow Eye), while in other cases it is wavy in outline or even greatly broken and bordered by very small spots irregularly grouped (Wardwell, Leopard). In the latter case the pigment sometimes extends from the main body of the eye-spot in a broken line at both ends of the bean, following in general direction the margins of the cotyledons and rarely meeting on the back of the seed, thus practically dividing the non-pigmented area into two side-spots. Eyed pigmentation is not to be confused with the hilum-

MOTTLED AND SELF PIGMENT PATTERNS.

When pigment is present in the seeds of beans, whether as partial or total pigmentation, it occurs either as a single solid color over the entire pigmented area,[17] "self color," or as a mosaic[18] of two or more colors or intensities of color, "mottling."

The various patches of color in mottled bean seeds vary greatly in size and shape. They sometimes take the form of narrow stripes running lengthwise of the seed or arranged somewhat concentrically about the eye. Sometimes they occur as irregular splashes. Very commonly they are mere specks. Where light and dark colors are associated in a mosaic, the pattern is very distinct. When the colors are all dark or all light, the pattern is correspondingly indistinct. Even in case of plants with normally distinct mottling, the pattern may be less plain in individual seeds owing to the preponderance of the dark color. In case of normally indistinct mottling, the occasional predominance of one color makes it very difficult to distinguish between the mottled and self patterns. In some cases it is almost impossible to determine the pattern without the use of a lens.

Self-colored bean races crossed with mottled ones have yielded only mottled F_1 offspring. In F_2 mottled and self-colored individuals have occurred. The ratio of mottled to self on the whole has approximated 3: 1, tho in particular cases it has varied widely from this ratio. From similar crosses, Tschermak secured in F_2 58 mottled and 20 self-colored individuals.[19] A detailed statement of my crosses is given in the following table:

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[17] No account is here taken of the hilum-ring, which may be present in self-colored as well as in mottled beans.

[18] Notwithstanding that I have described mottled beans as a mosaic of various colors with white (Ann. Rpt. Nebr. Agr. Expt. Sta. **15**: 37; **17**: 65), I now incline to the belief that true white rarely occurs in the mosaic of colors. The light-colored spots often appear practically white by comparison with the darker pigments, but on direct comparison with white they usually prove to be distinctly colored. The direct comparison is most easily made in partially pigmented beans where light spots of the eye happen to lie adjacent to the white area outside the eye. Even tho true white spots may be found to occur as a regular constituent of the mosaic in mottled beans (see discussion, page 95), it would still ordinarily be possible to distinguish a "totally" pigmented bean containing white in the mosaic from a "partially" pigmented (eyed) one, owing to the distribution of the pigmented and white areas peculiar to the two types. The types would doubtless be just as distinct in inheritance as tho no white occurred in the mosaic. Our terminology merely would need revising.

TABLE V.—*Results of crossing self-colored with mottled beans.*

Parentage.	Number of plants.			
	F_1		F_2	
	Mottled.	Self.	Mottled.	Self
Currie *S.*[20] × Golden Wax *M.*[20]	2	0	33	9
Wardwell *M.* × Challenge Black *S.*	1	0	29	8
Red Valentine *M.* × Burpee Stringless *S.*	8	0	160	79
Burpee Stringless *S.* × Warwick *M.*	2	0	38	5
Paris *M.* × Ultra *S.*	10	0	46	18
Mohawk *M.* × Ultra *S.*	2	0	16	2
Mohawk *M.* × Scarlet Flageolet *S.*	4	0	9	3
Dwarf Horticultural *M.* × Scarlet Flageolet *S.*	2	0	...	...
Dwarf Horticultural *M.* × Ultra *S.*	1	0	...	...
Yellow Eye *S.* × Dwarf Horticultural *M.*	1	0	...	...
Total	**33**	**0**	**331**	**124**

[20] "*S.*" = self-colored, "*M.*" = mottled.

Thirteen self-colored F_2 plants yielded 72 self-colored F_3 ones. Similarly, 5 mottled individuals produced 45 plants with mottled seeds only. Again 48 other mottled F_2 plants gave rise to 110 mottled and 57 self-colored plants in F_3. In case of Stringless Green × Warwick, the individual plants were not kept separate in F_3 but the total number of seeds of the various families was determined. This makes it possible to separate the F_2 plants into homozygotes and heterozygotes, and the ratios in case of the latter are probably not greatly changed by this method. Four self-colored F_2 plants of this cross produced plants that yielded 692 seeds, all self colored. Seventeen mottled F_2 plants yielded in F_3 plants that produced 1704 seeds, all mottled. Twenty-two

× Burpee Stringless) was almost exactly 2: 1. In other cases (F_2 from Burpee Stringless × Warwick), the ratio was 7.6: 1. In the next generation, from F_2 heterozygotes of this same cross, there was a slight excess of self pattern.

LATENT MOTTLING.

In case of most of my crosses of self-colored with white races, the F_1 individuals have had mottled seeds, instead of self-colored ones as might have been expected. The details of these crosses follow:

TABLE VI.—*Results of crossing self-colored with white beans.*

Parentage.	Number of plants.					
	F_1			F_2		
	Mottled.	Self.	White.	Mottled.	Self.	White.
Scarlet Flageolet *S.* × Davis *W.*	2	0	0	6	1	4
Challenge Black *S.* × Davis *W.*	1	0	0	3	1	1
Davis *W.* × Challenge Black *S.*	3	0	0	18	5	6
Davis *W.* × Blue Pod *S.*	3	0	0	5	0	2
Blue Pod *S.* × Davis *W.*	4	0	0	13	4	10
Davis *W.* × Ultra *S.*	5	0	0	26	15	20
Marrow *W.* × Ultra *S.*	8	0	0	12	3	3
Ultra *S.* × Marrow *W.*	14	2[21]	0	13	1	12
Ultra *S.* × Navy *W.*	13	2[21]	0	10	9	4
Navy *W.* × Challenge Black *S.*	3	0	0	7	13	8
German Black *S.* × Hybrid 102 *W.*	1	0	0	...	..	..
Hybrid 102 *W.* × German Black *S.*	7	0	0	...	..	..
Jones Stringless *W.* × Burpee Stringless *S.*	1	1	0	...	..	..
Total	65	1(+4[21])	0	113	52	70

[21] Doubtless pure Ultra. See text.

As a result of nine different crosses including five white races and six self-colored ones, there were secured in F_1, as seen from the table, 65 plants with mottled seeds and 5 with self-pigmented ones. Four of the five with self pattern were undoubtedly not hybrid at all but merely the result of faulty emasculation of the flowers cross-pollinated. In case of one attempted cross of Ultra by Marrow, the resulting pod contained four seeds. Two of the four plants that grew had the dwarf, bushy habit, long slender pods, and long, rather slender, orange brown seeds characteristic of the mother parent, Ultra. The other two plants, however, were tall, with a tendency toward runners and had rather broad, flat pods and rather plump, orange-brown mottled seeds, like all the other twenty F_1 individuals of the Ultra-Marrow cross. In case of the Ultra-Navy cross, one attempt resulted in three seeds. Two of these, just as in the preceding case, produced individuals typical of Ultra, the mother parent, in every way. The other seed from the same pod, however, produced a plant like all the other twelve F_1 plants of the Ultra-Navy cross. The plant was distinctly "viny" in habit. The pods showed plainly the influence of the short Navy pod with its short, abrupt point. The seeds moreover were small, plump, and black mottled. Unfortunately none of the seeds of these four self-colored plants were planted, but I have no hesitancy in pronouncing them pure Ultra.

This leaves only one F_1 plant with self-colored seeds. This was one of two plants produced from a single flower of Jones Stringless cross-pollinated by Burpee Stringless. Both plants were doubtless true hybrids. They had the green pod-color of the pollen-parent and black seeds. In one case the seeds were of an even self black so far as could be determined. In case of the other plant, two of the 13 seeds were black mottled with dark gray. The mottling, tho unmistakable, was very indistinct owing to the slight difference between the gray and black of the mosaic and to the preponderance of the black color. If the other seeds of this plant, or any of the seeds of the other plant, were mottled, the pattern was not observed even with the aid of a lens.[22]

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[22] It may seem strange to class a plant as mottled when only two of its seeds were plainly so marked while eleven of them were apparently self colored. My reason for doing this is that, in case of many mottled races, there occur on the same plant with well mottled seeds some seeds that are scarcely or not at all mottled, just as in case of variegation in other plants. The fact that

In F_2, from these crosses of self with white races, as will be seen by referring back to Table VI, there occurred mottled, self, and white individuals. It will also be seen that the three lots do not bear quite the numerical relation to each other expected in a dihybrid. The ratio obtained was 113: 52: 70 while 132: 44: 59 would satisfy exactly the demands of theory. In short, there were too few mottled and too many self and white individuals, the excess of selfs and of whites being in almost exactly the same proportion. The possible significance of these ratios will be discussed later (pages 88 and 98).

It is regretted that so few of these crosses were tested in F_3 and that in these few cases so very few F_3 plants were grown. Of the white-seeded plants in F_2, fifteen produced 226 offspring, all white seeded. Seven mottled F_2 plants produced a progeny of 52, 22 of which were mottled, 19 self, and 11 white. Two mottled F_2 plants gave 13 mottled, 13 self, and no white individuals in F_3, while four others yielded 5 mottled, 5 white, and no self-colored ones, and two others produced only 6 plants all with mottled seeds. Of the self-colored plants of F_2, five yielded 63 F_3 offspring, all self-colored and nine yielded 80 self-colored, 29 white, and no mottled plants. This is sufficient to indicate (1) that the white-seeded F_2 plants were, as usual, homogametous with respect to the absence of pigment; (2) that there were two classes of F_2 self-colored individuals, one of which was homogametous with respect both to mottling and to the presence of pigment and the other of which was heterogametous toward the presence of pigment but homogametous to mottling; and (3) that there were two types of mottled F_2 plants, one heterogametous to both presence of pigment and presence of mottling and the other homogametous to the presence of pigment and heterogametous to the presence of mottling. Whether the other two possible classes existed or not among the F_2 mottled individuals can not be determined from my records. The four classes would be expected to occur in the ratio of 4: 2: 2: 1. The first and second were present, but the third and fourth were not demonstrated, which is not strange when only fifteen mottled F_2 plants were tested and eight of them produced too few offspring to make the test of value. Both Tschermak[23] and Shull[24] report that no mottled individuals arising from their crosses of white with self-colored races have ever bred true to the mottled pattern.

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[23] *Loc. cit.* p. 46.

Before proceeding to a discussion of the theories that have been advanced to account for latent mottling, I shall present the results of crossing white with mottled races, the details of which are shown in the following table:

TABLE VII.—*Results of crossing mottled with white beans.*

Parentage.	Number of plants.					
	F1			F2		
	Mottled.	Self.	White.	Mottled.	Self.	White.
Wardwell *M.* × Davis *W.*	1	0	0	2	0	3
Keeney Rustless *M.* × Davis *W.*	1	0	0	3	0	2
Marrow *W.* × Paris *M.*	30	0	0	39	0	13
Navy *W.* × Paris *M.*	17	0	0	31	0	8
Paris *M.* × Navy *W.*	6	0	0	21	0	4
Navy *W.* × Wardwell *M.*	1	0	0	4	0	3
Wardwell *M.* × Navy *W.*	2	0	0	3	0	1
Navy *W.* × Warwick *M.*	1	0	0	...	...	..
July *W.* × Warwick *M.*	1	0	0	...	...	..
Jones Stringless *W.* × Hybrid 57 *M.*	2	0	0	...	...	..
Hybrid 57 *M.* × Jones Stringless *W.*	4	0	0	...	...	..
Total	**66**	**0**	**0**	**103**	**0**	**34**
Jones Stringless *W.* × Golder Wax *M*	**1**	**0**	**0**	**12**	**2**	**7**

Thus in F_1 from nine crosses of six mottled with five white races there were 67 plants, all with mottled seeds. While there was considerable variation between the different crosses in F_2, the ratio of mottled to white from all the Davis, Marrow, and Navy crosses was 103: 34, which is as near the Mendelian ratio of 3: 1 as it is possible to get from 137 individuals. Only a few F_3 plants were grown from these crosses.

Of the F_2 plants produced from the cross Jones Stringless × Golden Wax, 12 were mottled, 2 self-colored, and 7 white. The 7 white F_2 plants yielded 45 F_3 plants, all with white seeds. One of the two self-colored F_2 plants gave in F_3 9 self-colored and 2 white plants and the other one gave 5 self-colored plants and no others. One F_2 mottled plant gave 8 mottled and no other offspring. Seven other mottled F_2 plants gave in F_3 22 mottled, 17 self, and 22 white individuals.

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[24] Shull, G. H. Amer. Nat., **42**: 439.

THEORIES REGARDING MOTTLING.

My first crosses of white with self-colored races that resulted in mottled F_1 seeds were considered to be mosaics of the colors seen in the parents,[25] tho even at the time it was noted that the colors found in the mottled seeds did not always correspond to the colors of the parents.[26] Later I still regarded the mottling as a mosaic of the parent colors, but could not explain the behavior in F_2 and F_3 on the assumption that the mosaic was the heterozygote of a monohybrid.[27]

Tschermak[28] regarded mottling as a pigment pattern inherited separately from pigment and interpreted the occurrence of mottled F_1 offspring from a cross of self by white beans as due to the presence of mottling in a latent (inactive) condition in the self-colored parent. He also believed that not all self-colored races ("Hundert für Eine," for instance) had this latent character. He furthermore recognized two sorts of mottling. The one, brought from latency by crossing (Kreuzungsnovum), he regarded as an ever-sporting variety yielding both mottled and self-colored individuals in equal numbers. The other, existing as a visible parent character (Elternmerkmal), he considered to be a constant Mendelian character.

In 1905, Hurst[29] suggested to me that "the mottled character is a unit pairing with self-colour and probably dominant to it and that it was carried in a latent state by the white-seeded race which was probably originally extracted from a mottled hybrid." He also predicted that with large numbers the F_2 plants would be mottled, self, and white in the ratio of 9: 3: 4.

Shull[30] also considered the factor for mottling to be latent (invisible) in the non-pigmented parent race. He assumed two factors, *P* or *p* for the presence or absence of pigment and *M* or *m* for the presence or absence of mottling. The self-pigmented parent was believed to have the gametic formula *Pm* and the white parent the formula *pM*, from which on crossing there resulted, in F_1, *PM*, or mottled, pigmented individuals. It was expected that in F_2 three visibly different classes would appear in the dihybrid ratio of 9: 3: 4. With regard to the ratio, however, this expectation was not borne out by his results. The ratio of mottled, self, and white was approximately 6: 6: 4,[31] the mottled and self-colored F_2 plants occurring in practically equal numbers, as Tschermak had previously reported. To account for this, Shull proposed the following hypothesis: "Individuals which carry the mottled pattern, *M*, but are homozygous with respect to that character, are not mottled but self-colored. * * * The mottled color pattern must be heterozgyous in order to become apparent in the hybrids." Of the nine individuals carrying the factor *M*, expected in an F_2 progeny of sixteen, six should be heterozygous with respect to *M* (*PM.Pm* or *PM.pm*) and should, therefore, according to the hypothesis be mottled. The other three should be homogyous toward *M* (*PM.PM* or *PM.pM*) and should, therefore, be self-colored. These three, added to the three normally self-colored individuals, i. e., those that do not carry *M* (*Pm.Pm* or *Pm.pm*), from which they are not visibly different, make up the six self-colored individuals observed on the average in an F_2 progeny of sixteen.

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[25] Ann. Rept. Nebr. Agr. Expt. Sta. **15**: 37, 38 (1902).

[26] Ibid. p. 42.

[27] Ann. Rept. Nebr. Agr. Expt. Sta. **17**: 64-67 (1904).

[28] *Loc. cit.*, pp. 47, 51.

[29] Personal correspondence.

[30] Shull, G. H. Science, n. s., **25**: 792-794, 828-832 (1907).

As pointed out by Shull, two important considerations follow necessarily if this hypothesis is correct. (1) The mottled pattern made visible by crossing could never be "fixed," since then, by hypothesis, it would become latent (invisible). (2) The mottled pattern can be latent in self-pigmented individuals (*PM.PM*), as Tschermak believed, just as truly as it can be latent in a non-pigmented individual (*pM*).

While remembering that mottling, when brought forth from latency by crossing, does not breed true (at least in some cases), we must not forget that there are mottled races of beans that breed true to mottling. Tschermak recognized these two sorts of behavior and Shull raised the question as to their interrelation. In a recent paper,[32] I offered a hypothesis to explain the relation of the mottling seen only in the heterozygous condition to the mottling that breeds true, assuming that they are two distinct characters inherited independently of each other. I let M represent the true-breeding sort of mottling and X the sort that does not breed true and pointed out that there might then be eight possible gametic formulas for pure bean races, as follows:

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[31] **Amer. Nat. 42: 433-439.**

1. PMX, mottled, or self with mottling latent.
2. PMx, mottled.
3. PmX, self, mottling latent.
4. Pmx, self, without latent mottling.
5. pMX, white, both mottlers latent.
6. pMx, white, one mottler latent.
7. pmX, white, other mottler latent.
8. pmx, white, neither mottler latent.

Further, I endeavored to show that, whether X is hypostatic to M or the reverse, the above formulas could be assigned to the different races of beans that have been used in crossing so that the various results secured by Tschermak, Shull, and myself might be readily explained. But while the hypothesis explains the results that have been secured thus far, it suggests results that have not as yet been secured. A further test of the hypothesis, made by crossing a white race assumed to have formula 7 (pmX) with a mottled race (PMX or PMx), should, if the hypothesis is correct, result in mottled, self, and white individuals in F_2 in one of the three following ratios, none of which has a familiar look to the student of Mendelian inheritance, namely, 11: 1: 4, 21: 3: 8, or 33: 15: 16. If one or other of these ratios should be obtained, or approximated closely, when large numbers are dealt with, it would not only add another observation in accord with the hypothesis, but would indicate the relation of X to M. If either one of the first two ratios is produced, X is hypostatic to M, while if the third ratio is found, X is epistatic to M. The ratios of mottled to self in these cases, 11: 1 or 7: 1 in the first case and practically 2: 1 in the second case, are so unlike that it should not be difficult to determine quite positively the relation of the two characters. Other equally reliable tests can be made to determine this relation, as, for instance, crossing a self race having formula 3 with a mottled race having formula 2 ($PmX \times PMx$).

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[32] Amer. Breeders' Assoc., **5**: 368-376.

Notwithstanding the ready explanation of all the known facts by Shull's hypothesis as extended by myself, I nevertheless protested mildly in a recent paper (*loc. cit.*) against the unreasonableness of it in these words: "Shull's later hypothesis, then, seems to fit the facts well, and I can see no way but to accept it tentatively at least, even tho it is extremely difficult for me to conceive of a character of such a nature that it is expressed in the soma when received from one parent and not expressed when it comes from both parents." Since the publication of my paper, Spillman[33] has offered an explanation that seems much more reasonable. He says: "Let us suppose that the mottled races which reproduce true have in them two correlated factors. I think of this as a single chromosome which throws off into the cell two chemical substances which react with each other, giving a product which causes the mottling, tho it may not be a chromosome but rather a piece of a chromosome in which these two factors reside. At any rate the two factors are tied together and transmitted together. If this hypothesis is true then there could be three types of non-mottled beans, namely, a type resulting from the loss of one of the correlated factors; second, a type resulting from the loss of the other correlated factor; and third, a type resulting from the loss of both correlated factors." Spillman, in the correspondence referred to, goes on to show, by means of appropriate formulas, that his correlation hypothesis fits all the cases mentioned in my paper.

In what follows I have preserved Spillman's correlation hypothesis but have modified his formulas to correspond with the forms used elsewhere in this paper. Calling one of the factors *Y* and the other Z, or y and z if absent, and indicating gametic coupling thus, $\widehat{YZ}$, the eight possible pure types become:

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[33] Personal correspondence, June 7, 1909.

9. $P\widehat{YZ}$, mottled.
10. $P\widehat{Yz}$, self, one mottler latent.
11. $P\widehat{yZ}$, self, other mottler latent.
12. $P\widehat{yz}$, self, neither mottler latent.
13. $p\widehat{YZ}$, white, both mottlers latent.
14. $p\widehat{Yz}$, white, one mottler latent.
15. $p\widehat{yZ}$, white, other mottler latent.
16. $p\widehat{yz}$, white, neither mottler latent.

We can assign a definite formula to each of the races that have been used in crossing such that all the results known to me will be accounted for, with the exception that some white races (Navy, Tables VI and VII) must be assumed to be mixed, some plants having formula 13 and others 14 or 15. No amount of cross breeding between the individuals of such a white race would reveal the mixture.

Either one of the two hypotheses under consideration explains the facts now known. The independent-factor hypothesis seems to me on the whole less probable than the coupled-factor hypothesis. One of the difficulties with it is its assumption of two entirely independent factors the visible expressions of which are identical, an assumption not found necessary in explaining the inheritance of other characters. Another difficulty is the necessity of assuming a factor of such peculiar nature that it is visibly expressed only in the heterozygote condition. Gametic coupling, the fundamental idea in Spillman's hypothesis, is a less difficult conception and furthermore may have wide application to plant and animal characters. The idea of two factors being necessary for the expression of a character is not new, such characters being known in both plants and animals. If this coupled-factor hypothesis is true, latency of mottling in self-colored beans is due to *separation* of the factors just as in case of latency of color modifiers in white beans rather than due to *combination* as suggested by Shull.[34]

It should be possible by means of appropriate crosses, many of which I now have growing, to determine quite positively which one, if either, of these hypotheses is correct. It may then be soon enough to inquire whether any other characters in plants or animals are constituted in this peculiar way. It seems worth while, however, to mention in passing that variegation in other plants, as well as mottling (variegation) in beans, should prove an interesting field for investigation in this connection. In some cases, certainly, variegation breeds true, for instance red-striped pericarp in maize (Calico corn). In case of some other plants,[35] variegation does not breed true. Further, if I am rightly informed, "Speckled Squaw" corn, a type of flour corn with mottled black and white aleurone, breeds true to this ever-sporting character. Lock,[36] however, has shown that a similar mottling, occurring in crosses of white with black races of maize, does not breed true but tends to disappear in a few generations. It seems possible, therefore, that mottling in corn may be due to definite factors for mottled aleurone, similar to the *M* and *X* or *Y* and *Z* factors in beans, instead of being produced by separate division of the second generative nucleus and of the fused polar nuclei (Webber's first hypothesis) or by the separate division of one polar nucleus and of the nucleus formed by the fusion of the other polar nucleus with the second generative nucleus (Webber's second hypothesis).[37] As pointed out in my previous papers[38] certain races of beans having yellow pods with no red markings or only slight traces of red, when crossed, produce F_1 plants with yellow pods almost covered with bright red specks and splashes. While the matter has not been fully investigated, the indications are that plants which as a result of crossing have intensely colored pods are heterozygous with respect to the red variegation. Some well-known races of beans, however, have pods brilliantly marked with red and breed true to this character regularly. It may even turn out that certain characters of cotton hybrids, described by Cook as being given expression or as being intensified by crossing but which disappear in later generations, green fuzz for instance, are of the same nature as the X factor or the Y and Z factors in beans.[39]

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[34] Shull, G. H. Amer. Nat. **42**: 439-441.

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[35] Bauer, E. Ber. Deutsch. Bot. Gesell. **25**: 442-454 (1907).

[36] Lock, R. H. Ann. Roy. Bot. Gard. Peradeniya **3**: 119.

[37] Webber, H. J. U. S. Dept. Agr., Div. Veg. Phys. and Path., Bul. 22, pp. 34, 37 (1900). Some of my own unpublished results with corn crosses, if I have rightly interpreted them, make Webber's first hypothesis untenable. If the second generative nucleus on the one hand, and the fused polar nuclei on the other, divide separately, each forming "islands of tissue," a cross of a black sugar corn with a white or with a yellow starchy corn should not only result in mottling of the black aleurone color as actually occurs but cause the black "islands" to be uniformly hyaline and the white or yellow ones to be starchy. Both White Rice and Golden Queen pop corn crossed with pollen of Black Mexican sugar corn yielded a large percentage of kernels that were mottled black and white or black and yellow according to the cross, but all were starchy thruout. Furthermore the black spots of the mottled grains from the Golden Queen-Black Mexican cross were underlaid by yellow endosperm in every case, which could not have occurred if the second generative nucleus, bearing the character of non-yellow endosperm, had alone given rise to any part of the endosperm beneath the aleurone.

THE RELATION OF MOTTLING TO COLOR HYPOSTASIS.

Shull[40] has shown that certain bean colors are hypostatic to other colors. Thus light yellow (the color seen in Long Yellow Six Weeks) is hypostatic to orange-brown (seen in Ultra), orange to dark brown, and dark brown to black. He has shown that the black race Prolific Black has dark brown latent by hypostasis and that the orange-brown Ultra has light yellow latent in the same way. My cross of Burpee Stringless by Giant Stringless,[41] the former dark brown and the latter orange-brown, indicates that orange was latent by hypostasis in the dark brown race. In F_2, brown-seeded and orange-seeded plants occurred, but there were no other colors. If orange is not latent in the dark brown race, some other color still lower in the scale than orange should have shown itself in F_2. By a cross of Challenge Black with Scarlet

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Some doubt is thrown upon Webber's second hypothesis by the fact that white corn pollinated by yellow corn produces grains that are yellow or yellowish thruout but never, so far as I am aware, grains that are mottled yellow and white.

[38] *Loc. cit.* **15**: 41, 42; **17**: 59.

[39] Cook, O. F. U. S. Dept. Agr., Bureau Plant Indus., Cir. 18 (1908) and Bul. 147 (1909). It is greatly to be regretted that Cook has not published a detailed account of the results upon which the generalizations presented in these papers are based. So full of suggestion are the brief statements of fact given, that publication in detail of the pedigree records will be awaited with the greatest interest by all students of heredity.

[40] Amer. Nat. **42**: 443-446 (1908).

[41] Ann. Rpt. Nebr. Agr. Expt. Sta. **17**: 61-64 (1904).

Flageolet, I have found dark red to be hypostatic to black. From a cross of Scarlet Flageolet with Ultra, the few somewhat discolored seeds were recorded as yellow-brown. This indicates that red may be hypostatic to orange-brown.

Some years ago I crossed the dark brown bean Burpee Stringless with the reddish purple mottled bean Warwick. My notes are very unsatisfactory from the standpoint of color descriptions, but nevertheless they show plainly that there were in F_2 and F_3 with respect to color only two classes of self-colored beans and at least four classes of mottled beans. The self colors noted were dark brown and a sort of orange-brown. In some of the mottled seeds dark brown predominated and in others orange-brown. In some of the former, and also in some of the latter, red was noted while in others it was not. My notes indicate that there may also have been a purplish color present in some of the mottled seeds. The important point, of which there can be no doubt, is that there were more kinds of mottled seeds than of self-colored ones. If we may assume that Burpee Stringless has the formula *mDOr* and Warwick the formula *MdOR* (*M* representing mottling, *D* dark brown, *O* orange, and *R* red), there should occur in F_2 the following forms in the relative numbers given:

27 *MDOR*, mottled dark brown (and orange and red?).
9 *MDOr*, mottled dark brown (and orange?).
9 *MdOR*, mottled orange (and red?).
3 *MdOr*, mottled orange.
9 *mDOR*, self dark brown, orange and red latent.
3 *mDOr*, self dark brown, orange latent.
3 *mdOR*, self orange, red latent.
1 *mdOr*, self orange.

From this there could be only two visibly different sorts of self-colored beans, namely, dark brown and orange. There might, however, be four sorts of mottled beans, all visibly different, *if hypostatic colors are visible when present in mottled seeds.* This assumption, if true, will explain the facts observed. The suggestion may seem more reasonable when it is recalled that many mottled beans exhibit a mosaic of several distinct colors. It is rare to find less than three colors, or intensities of color, in mottled beans. We can conceive of mottling as of such a nature that when present it prevents the development of a color in certain groups of cells, allowing it to develop in others, and that it acts upon the various colors independently. Then, from the formula *MDOR* we would expect dark brown to develop in some spots and not to develop in others. The same would be true of orange-brown. But the orange spot might overlap the dark brown one. Where the two were present together, only the brown would show, owing to the fact that orange is hypostatic to brown. Where the orange spot did not overlap the brown, however, it should be visible. In the same way, red might by chance appear in some spot where there was neither brown nor orange. In case some other color, hypostatic to all those named, were present, it might show itself in some small spots not occupied by the colors epistatic to it. In case no other color were present, a few small spots should be white. Where only two colors are present, it would seem that there should be white patches of considerable size. This, however, I have not observed to be the case.

RELATION OF COLOR HYPOSTASIS TO ALBINISM.

It is interesting to note some of the corollaries of the theory of hypostasis of colors. What will happen when two races having no color in common are crossed? If we cross *BdR* with *bDr*, there should occur in F_2 one individual in sixty-four with the formula *bdr*. In other words, about one and one-half per cent of the F_2 offspring should be *white*, tho having the factor *P*, which is lacking in case of the white beans discussed earlier in this paper.

It is possible that this is the explanation of the results recorded by Tschermak[42] and by Halsted,[43] both of whom have reported the occurrence of white beans from crosses of pigmented races. Tschermak crossed Wachsdattel, a self-colored, light yellowish brown bean, with Scarlet Runner, a bean with seeds mottled black and lilac-pink. From this cross numerous white-seeded individuals arose in F_4. Halsted also crossed a light brown bean, Tennessee Green, with Scarlet Runner and got white-seeded individuals in F_3. Tschermak states that his hybrid beans were grown at considerable distance from other sorts and calls attention to the fact that with respect to other characters the extracted pure types bred true. He believes that, while the possibility of accidental cross-pollination in isolated cases is not precluded, the results could not have been seriously modified thereby. Halsted's hybrid beans were also grown in somewhat isolated plats, but he recognizes the possibility that they may have been crossed thru insect agency.[44] If the production of white-seeded plants in these cases was due to accidental crossing with some white-seeded race, the cross must have been made on F_1 plants in case of Halsted's beans and on F_2 plants in Tschermak's case in order that its effect might become visible in F_3 and F_4 in the respective cases.

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[42] *Loc. cit.*, p. 78.

[43] Halsted, B. D. Rpt. Bot. Dept. N. J. Agr. College Expt. Sta. **1906**: 473-476; **1907**: 346-349.

It is significant that in no other of the numerous crosses of pigmented beans recorded by Tschermak and Halsted is the occurrence of non-pigmented beans reported, so far as I am aware. A fact of even greater significance, perhaps, is that the cross resulting in the production of white beans, in both Tschermak's and Halsted's experiments, was between a light brown bean and Scarlet Runner. The latter doubtless contains no brown, for if brown were present it should show as one of the components of the mosaic. The brown-seeded parents certainly have no latent black since brown is hypostatic to black, and probably have no reddish or purplish color. The two parents, if they have no color in common, should produce, on being crossed, a small but definite per cent of white-seeded plants in F_2. The fact that white seeds were not seen until generations later than F_2 is probably to be accounted for by the fact that too few F_2 plants were secured.

Halsted suggests that "The 'Scarlet Runner' has a white-seeded strain, and the seed used for the hybrids in question may have contained more or less of this white character, obscured by the mottled purple of the normal seeds. In like manner the light of the F_1 plants should have produced in F_2 one white-seeded plant in every four. Or, if both original parents had white recessive, one-fourth of the F_1 plants should have been white-seeded. With so great a chance as one in four, white seeds would almost certainly have been produced in F_1 or F_2. It is probable that Tennessee would have manifested no "tendency to produce white" if it had been crossed with a race having brown either visible or latent and similarly that Scarlet Runner would not have shown the "tendency" if it had been crossed with a race having either black or reddish purple.

It is not correct, in discussing the occurrence of white in these crosses, to say that white was latent in either parent. White in beans is here regarded not as a positive character but merely as the absence of pigment or of all pigment modifiers or of both pigment and pigment modifiers. Black, or any other pigment modifier, can be latent (invisible) in a white bean on account of separation from pigment. Likewise pigment can be latent in a white bean due to separation from all pigment modifiers. We are here concerned with latency due to *separation* rather than to *hypostasis*.[45] The matter has been discussed under the head of the relation of albinism to hypostasis, for the reason that it is only by regarding color relations as a matter of *hypostasis* rather than of *dominance* that the explanation offered here, to account for the production of white beans from colored parents, could have been arrived at.

White beans thus produced, i. e., by the loss of all color modifiers, crossed with ordinary white beans, those lacking pigment but having pigment modifiers, should result in the production of colored beans in F_1 ($Pbdr \times pBDR = PBDR$, for instance). The fact that this has been done with sweet peas[46] would make it seem not unreasonable to expect similar results with beans.

White beans having pigment but no pigment modifiers, crossed with pigmented beans, should produce in F_2 pigmented and white offspring in the ratio of 3: 1 only when the pigmented parent has a single color modifier. If the pigmented parent has two colors, the F_2 ratio should be 15: 1, if three colors 63: 1, four colors 255: 1, five colors 1023: 1, and so on, approaching $\infty : 1$. If the white parent bean has neither pigment nor pigment modifiers, crossing it with a pigmented bean having but one color modifier should give an F_2 progeny of pigmented and white individuals in the ratio of 9: 7, or 1.29: 1. If the pigmented parent has two color modifiers, the ratio should be 45: 19, or 2.37: 1; if three colors, 189: 67, or 2.82: 1; if four colors, 765: 259, or 2.95: 1; and so forth, constantly approaching but never reaching the ratio of 3: 1. As pointed out in the first part of this paper, the crossing of non-pigmented beans with pigmented ones results in an F_2 ratio approximating 3: 1, but with a slight excess of whites (pages 71 and 85). This excess is to be expected in all cases where none of the visible or latent colors of the pigmented parent are the same as the latent colors of the white parent. The percentage of this excess of whites will depend upon the combined number of color modifiers present in the two parents. If the combined number is two, each parent having a single modifier, the F_2 ratio should be 2.37: 1; if three or four, 2.82: 1 or 2.95: 1, respectively, in no case reaching quite 3: 1. Such speculations as these have their chief value, perhaps, in making one cautious about announcing "exceptions" to Mendelian behavior on the mere basis of ratios that one is at the time unable to explain.

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[45] Shull, G. H. Amer. Nat. **42**: 439, 443.

[46] Bateson, W. Hort. Soc. N. Y. **1**: 5 (1902).

SUMMARY.

The presence of pigment, P, in bean seeds is dominant to the absence of pigment, p, the two conditions constituting an allelomorphic pair inherited in typical Mendelian fashion.

Total pigmentation dominates partial (eyed) pigmentation in F_1. In F_2 both forms occur. Eyed F_2 individuals are always homozygous while some totally pigmented ones are homozygous and some are heterozygous. This would be the expected result if total pigmentation and eyed pigmentation constituted a simple Mendelian character-pair. In keeping with recent Mendelian tendency, the pair is here considered to be presence, T, and absence, t, of total pigmentation. In the absence of T, the beans used in these experiments have shown eyed pigmentation. It is probable, however, that the eyed condition really depends upon the presence of a distinct character, E, and it is possible even that there may be two or more distinct characters, E', E'', etc., concerned. No bean has yet been shown to lack E.

Total pigmentation is latent in certain non-pigmented (white) beans, *pT*. Crosses of these white races with eyed races give totally pigmented, eyed, and white offspring in F_2. These same white races, when crossed with totally pigmented ones, as is to be expected yield no eyed individuals in F_2.

Mottled pigment-pattern is dominant to self-color. When mottled races are crossed with self-colored ones, the F_1 individuals are mottled and in F_2 both mottled and self-colored individuals occur. The latter breed true while some of the former breed true and some produce the two types again.

Certain white beans crossed with self-colored ones produce mottled offspring in F_1 and mottled, self, and white individuals in F_2, while other white beans similarly crossed produce self-colored F_1 plants. This indicates, tho, as pointed out by Shull, it does not prove, that mottling may be latent in some white beans and not in others. So far as the experiments here reported are concerned, white beans of the type first noted, when crossed with mottled races, give mottled individuals in F_1 and only mottled and white ones in F_2, while white beans of the second type yield, from similar crosses, self-colored as well as mottled and white individuals in F_2.

In the tests here reported, crosses of various self-colored races have produced nothing but self-colored offspring. Tschermak, on the contrary, secured mottled F_1 offspring from one such cross, indicating that mottling might be latent in self-colored beans.

The results of most of my own experiments might be explained as due to Mendelian behavior of an allelomorphic pair, *M*, *m*, presence and absence of mottling, *M* being visible only in the presence of *P*. The results of Shull and Tschermak—(1) an F_2 dihybrid ratio of 6:6:4 instead of 9:3:4 from a cross of self-colored with white beans, (2) the failure of any of the mottled F_2 individuals to breed true, and (3) mottled F_1 offspring from a cross of self-colored races—cannot be explained in this way. Two hypotheses have been suggested to account for the facts known. The first, or independent-factor hypothesis, assumes two factors, *M* and *X*, inherited independently of each other, their only relation to each other being that due to hypostasis. *M*, the factor responsible for the color pattern of ordinary mottled races, is assumed to behave as most Mendelian factors do, while *X* is supposed to be of such a nature that it is visible only in the heterozygous state, as suggested by Shull. The second, or coupled-factor hypothesis, suggested by Spillman, assumes two factors, *Y* and *Z*, such that mottling becomes visible only when both are present together, and assumes that they are coupled in inheritance. Such relations as those suggested by these hypotheses offer an interesting field for further investigation.

The mottling character is conceived to be of such a nature that when present it prevents the development of a color in certain groups of cells, allowing it to develop in other cells, and such that it acts toward the different colors independently. This would make it possible for any color to be visible in mottled seeds, even in the presence of colors epistatic to it. Evidence in support of this is furnished by a cross of a mottled race with a self-colored one which resulted in only two sorts of self-colored seeds and at least four sorts of mottled seeds in F_2.

Crossing any two pigmented beans that have no color in common should result in the production of a definite percentage of white-seeded individuals in F_2, the white color being due to the absence of all pigment modifiers, *B*, *D*, *R*, etc., rather than to the absence of pigment, *P*. This may account for the occurrence of white beans in both Tschermak's and Halsted's crosses of a black-red mottled bean with a brown one. Crossing a white bean thus produced with a white one having latent pigment modifiers should produce colored F_1 offspring.

Heretofore the expectation from a cross of pigmented with white beans has been an F_2 ratio of 3: 1. This should not occur, however, except in cases (1) where the white parent lacks pigment and has at least one pigment modifier in common with the pigmented parent and (2) where the white parent has pigment but lacks all pigment modifiers and the pigmented parent has only a single pigment modifier. Crossing white beans that lack pigment but have pigment modifiers with colored beans having different pigment modifiers should result in colored and white individuals in F_2 in ratios from approximately 2.4: 1 to nearly 3: 1, according to the combined number of pigment modifiers present in the two parents. The greater the combined number, the nearer the ratio approaches 3: 1. This may account for the excess of whites over the one-fourth expected in my crosses of white with colored beans. Similarly F_2 ratios of from about 1.3: 1 to nearly 3: 1 should be had from crosses of pigmented beans with white beans that have neither pigment nor pigment modifiers, the latter ratio being approached closely only when the number of color modifiers in the pigmented parent is large. Again crosses of colored beans with white ones that have pigment but lack pigment modifiers should result in F_2 ratios of from 3: 1 to ratios approaching ∞ : 1 the ratio increasing with the increase in the number of pigment modifiers in the colored parent.

THE LIFE HISTORY OF THE CEDAR RUST FUNGUS

Gymnosporangium juniperi-virginianae Schw.

By F. D. Heald, Ph. D.

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THE LIFE HISTORY OF THE CEDAR RUST FUNGUS

Gymnosporangium juniperi-virginianae Schw.

By F. D. Heald, Ph. D. *

INTRODUCTION.

The general prevalence of the disease known as the "cedar rust" thruout the eastern half of the state together with the resultant injury to cedar trees and the apple crop has led to repeated inquiries in regard to the nature of the disease and methods for its prevention. The early study of the disease led the writer to the belief that the cycle of development of the fungus which causes the disease is not in accord with the generally accepted opinions. Before it is possible to combat any disease intelligently, the life history of the causal organism must be known, hence the study of the "cedar apple" fungus was undertaken as a special problem. The special points in which the fungus has been observed to deviate from the generally accepted ideas will be noted in the consideration of its life history.

DISTRIBUTION IN NEBRASKA.

The reports received in the Plant Disease Survey during the past few years show that the disease in question is very abundant thruout the eastern part of the state. The abundance of the disease in the section indicated is due at least in part to the general practice of employing the cedar as an ornamental tree and for windbreaks around orchards. Add to this fact the extensive

CAUSE OF THE RUST.

The cedar rust is caused by *Gymnosporangium juniperi-virginianae*, which lives at one stage of its life history upon the cedar (*Sabina virginiana*) producing the so-called "cedar apple," while a second stage in its cycle of development is passed upon the leaves, fruit or twigs of the cultivated apple or some other pomaceous host where it produces the stage known as the cluster-cup, which is the aecial stage of the fungus. These facts have long been known to scientists, and yet we find some practical orchardists who still insist that there is no relation between the "cedar apples" and the apple rust.

THE LIFE HISTORY OF THE FUNGUS.

THE PRODUCTION OF SORI.

The "cedar apples" remain dormant during the winter period, but with the first warm damp weather of spring they begin to put out the yellowish or orange projections, or sori. The galls vary in size from about that of a radish seed to two inches in diameter and they may produce from one to several dozen sori. (See figs. 1 and 2.) When the gelatinous projections are fully formed they give the diseased trees quite a striking appearance, especially when the galls are very abundant, and some uninformed people admire these structures thinking they are the flowers of the cedar. (Fig. 3). In cases of light infection the majority of apples produced will be of medium size, while in severe infections the greater number will be small as shown in the illustration (fig. 1). In severe infections, the weight of the numerous apples is frequently sufficient to cause a conspicuous drooping of the branches.

GERMINATION OF TELIOSPORES.

Each gelatinous mass is filled with the two-celled teliospores the promycelium will be short and compact (fig. 4a), but with increase in the water supply a more elongated growth results (fig. 4b). Under favorable conditions the promycelium will be produced and the sporidia matured in 12 to 24 hours. In the initial stages of the germination, the cells of the promycelium have granular orange-colored contents, but with the production of the sporidia they become hyaline and empty and the sporidia alone retain the granular pigmented protoplasm. Some deviations from the normal development are shown when some of the promycelial cells fail to produce sporidia or grow out into somewhat elongated branches, and also when sporidia are produced direct from the side of the teliospore without the previous formation of a promycelium (fig. 4, c, d).

GERMINATION OF SPORIDIA AND INFECTIONS.

As soon as the gelatinous sori begin to dry, the sporidia are carried away by the wind and many of them fall upon the surface of adjacent foliage. In case conditions are favorable they germinate, each one giving rise to one or two infection threads (fig. 5). Those spores which fall upon the leaves, young fruits or twigs of susceptible varieties of apples produce infections by the entrance of the infection threads thru stomata into the tissues of the host. During a given season, one or more crops of sporidia may be produced, but generally the first crop is much the largest. During the three years in which the disease has been under study at Nebraska, the number of crops of sporidia has been either two or three, with corresponding periods of infection.

NORMAL SYMPTOMS OF RUST ON THE APPLE.

The rust shows first on the upper surface of the leaves as pale yellow spots about the size of a pin-head. These spots begin to show a week or ten days after the "cedar apples" have been in the gelatinous condition. The actual infection, however, takes place during the first 12-24 hours following the drying of the sori, and the remainder of the time is occupied by the development of the fungus hyphae within the tissues of the host, and finally with sufficient growth the external symptoms become evident. As the fungus grows, these spots become larger and assume a deeper color, finally becoming orange-colored. In a few weeks after the first appearance of the spots, minute pustules appear in the center of each, and these later show as small black specks. These black specks represent the openings of the pycnia, which are flask-shaped structures sunken in the tissue of the host. So far as is known at the present time they play no necessary part in the life history of the fungus.

With the continued growth of the fungus very little change is noticed in the spots on the upper sides of the leaf. The leaf tissue beneath the spots, however, begins to swell up until finally a cushion or blister one-fourth to one-half inch in diameter is produced. It is on these cushions of tissue that the aecia or cluster-cups are produced (fig. 6). When the aecia are young, each shows as a minute tubular projection with a brown mass of spores at the bottom, but when mature the wall of the tube may be split and recurved so as to give each a stellate appearance (figs. 7 and 9).

DEVIATION FROM NORMAL SYMPTOMS.

In some cases the attendant symptoms differ from what has just been described, which may be considered the normal course of infections. In severe infections of susceptible varieties of apples the leaves may turn yellow and fall from the tree before the aecia have been completed. The number of points of infection on an ordinary sized apple leaf may be as high as 200-300 in these severe cases. When a large number of infections have been started upon a leaf these spots are generally small, and often coalesce, while in less numerous infections the spots are of typical size and the leaves remain on the tree long enough to produce mature aecia. Severe infections may thus cause a very considerable amount of defoliation, while in light infections the leaves do not drop to any extent. In the case of resistant or slightly susceptible varieties of apples the rust spots remain minute and undeveloped for the entire season, at times not even being able to form the pycnia. This is noticeably the case in such a variety as the Ben Davis. Another deviation from the normal may be noted in certain cases in which the leaf tissue is killed at the point of infection so that a from one-eighth to one-fourth inch, never undergo any further development, but retain their characteristic Phyllosticta-like appearance (fig. 10). Later in the season these dead areas may be invaded by saprophytic fungi like *Cladosporium* or *Alternaria*, and their true nature would be difficult to determine if their development had not been followed.

TIME OF MATURITY OF THE AECIA AND FIRST APPEARANCE OF THE GALLS ON THE CEDAR.

Observations made during the past year have corroborated the statements previously made by the author in regard to the biennial character of the "cedar apple."[3] According to previous investigators the aeciospores produce infections upon the cedar which cause the development of "cedar apples" which mature in the fall and become gelatinous the next spring. The date for the maturing of the aecia in comparison with the time when the first "cedar apples" are visible on adjacent trees shows clearly that this can not be the case. The time of opening of the first aecia at Lincoln and the time of the first appearance of the "cedar apples" is given below for three years:

	Cluster-cups open.	"Cedar apples" distinctly visible.
1906	July 1	June 20?
1907	July 26.	June 17.
1908	July 10.	June 14.

It may be seen from this record that "cedar apples" are distinctly visible from ten days to four weeks before the aecia of that season are open and ready to permit the dissemination of spores for new infections. The accompanying photograph shows the size of the cedar apples (fig. 11) before the aecia have been formed on the leaves of adjacent apple trees. In the early stage of development the "cedar apple" is visible as a small green enlargement which originates from the stem in the axil of a scale and pushes the scale outward (fig. 12).

THE PERIOD OF REINFECTION OF THE CEDAR.

The period of reinfection of the cedar begins with the first production of viable aeciospores (July 1-26 according to forwardness or retardation of growth) and continues thruout the remainder of the growing season. During the month of October, only one to two per cent of the aeciospores are capable of growing at the temperature of the field or garden. This was determined by means of hanging-drop cultures made at different periods during the month. This would confine the reinfection very largely to the months of July, August, and September, and the spraying experiments to be described still further substantiate this view.

REVISED LIFE HISTORY OF THE FUNGUS.

A diagram has been constructed to express the revised idea of the life history of the "cedar apple" fungus based on the observations and experiments carried out (fig. 13).

The "cedar apples" or galls produce sori or become gelatinous during the month of May. The teliospores germinate *in situ*, and produce sporidia which infect the apple during the next few days. The first aecia become mature during the month of July and viable spores are produced in large numbers during this and the two following months. It is during these months that the infection of the cedar takes place, but no visible signs of the infection can be noted. The mycelium apparently remains dormant during the remainder of the season and the winter period and no "cedar apple" is produced since its production is dependent upon the growth of the cedar, which is slight or entirely inhibited at this period. With the resumption of growth in the spring, the fungus stimulates the tissues of the cedar at the point of infection and the result is the formation of "cedar apples," which first become visible in the month of June. These apples grow thruout the summer and fall and at the end of the growing season are practically mature in size and form. They remain dormant during the winter period, and with the return of conditions favorable to growth produce the characteristic gelatinous sori. It will be seen from the diagram that it requires twenty-three months from the time of infection of the cedar to the period when the resultant galls produce the gelatinous sori.

INJURY TO THE APPLE AND THE CEDAR.

The "cedar apple" fungus grows upon two hosts, the cedar and the apple, and is productive of injury to both. The earlier complaints were largely in connection with the stage passed upon the apple leaves and fruits. The injury to the orchard crop is twofold: first, the direct injury to the fruit; second, the injury to the foliage, which affects indirectly the possibility of fruit production; and third, the injury to the twigs.

In susceptible varieties of apples the young fruits may be very generally infected. The infection may be localized and result in a deforming of the fruit with a slight reduction in size, or the infection may be general over the surface causing a very marked atrophy of the fruit (fig. 14). The amount of injury which the rust causes to the apple foliage may be very great. In the susceptible varieties which stand adjacent to cedar trees, almost every leaf may be affected, frequently so seriously that the tree shows a pronounced yellow color even from a distance. In such cases a premature defoliation follows and thus sends the tree into its period of winter rest in a weakened condition.

The amount of injury to the cedar tree varies with the severity of the infection and the age of the tree. Artificial inoculations of young cedars with only needle leaves were attempted but were in all cases unsuccessful. The field observations in different parts of the State showed that trees from twenty to thirty years old were the most susceptible to infection and suffered the most from the presence of the parasite. In many places severely infected cedars were found to be dying and there can be little doubt that the fungus was responsible for their destruction. (Fig. 15.)

SPRAYING EXPERIMENTS.

Spraying of apple trees for the prevention of rust has met with varying degrees of success by orchardists in Nebraska[1,5] and the main reason for the failure is due to the quickness with which infection follows the gelatinous condition of the cedar apples. Experiments carried out by the writer showed that a delay of 12-24 hours was sufficient to make the spraying of no value.

No previous experiments in spraying the cedar are on record. It is obvious that the spraying might be designed to kill the teliospores, and so should be made when the "cedar apples" first become gelatinous, or should be made to prevent the reinfection of the cedar. Germination tests made from the teliospores of the telia sprayed with 5-6-50 Bordeaux showed the complete failure of the teliospores to produce sporidia. It does not seem, however, that spraying at this period will ever be practical. Some carefully planned spraying experiments to prevent the reinfection of the cedar were carried out during the season of 1907. Four blocks of small cedars in the Experiment Station orchard were sprayed with 6-6-48 Bordeaux plus three pounds of soap with the following results:

	1907	1908	1908
	Dates of Spraying	Average no. of galls per sprayed tree	No. of galls per control tree
Block I.....	July 26; Aug. 6, 15	48	950
Block II....	July 26; Aug. 6, 15, 29; Sept. 12, 26; Oct 9	140	1500
Block III...	Aug. 15, 29: Sept. 12, 26; Oct. 9	159	1400
Block IV...	Sept. 2, 12, 26; Oct. 9	1400	1450 estimated

The results show that spraying at intervals from the period of maturity of the aecia to September 1 very greatly reduced the number of "cedar apples." The results obtained from block IV, in which the spraying was started on September 2, indicate that the late sprayings are of little value. The majority of the infections take place during the months of July and August, with a very small amount during September and October. It was shown by germination tests that the aeciospores begin to lose their vitality during these months. On October 12 only 5 per cent of spores examined were capable of germinating at a temperature of 26-28 degrees C. while only 2.4 per cent germinated at field temperature.

The practical application of spraying cedars for the prevention of "cedar apples" must depend largely upon the local conditions. The reduction of the number of galls is not sufficient to be of much value in preventing the infections of adjacent apple trees, but if the life of valuable cedars is being threatened by the abundance of the fungus, spraying should reduce the ravages of the fungus sufficiently to prevent any material injury to the cedars.

The writer desires to acknowledge valuable assistance from the following in carrying out the work outlined:

Miss Venus W. Pool, for germination tests of spores and the drawing of the aecia; Prof. H. W. Barre, now of Clemson College, S. C., for field observations and laboratory assistance; Mr. W. H. Hein, for assistance in spraying the cedars; and Mr. F. A. Wolf, now of the University of Texas, for assistance in completing the records of the spraying.

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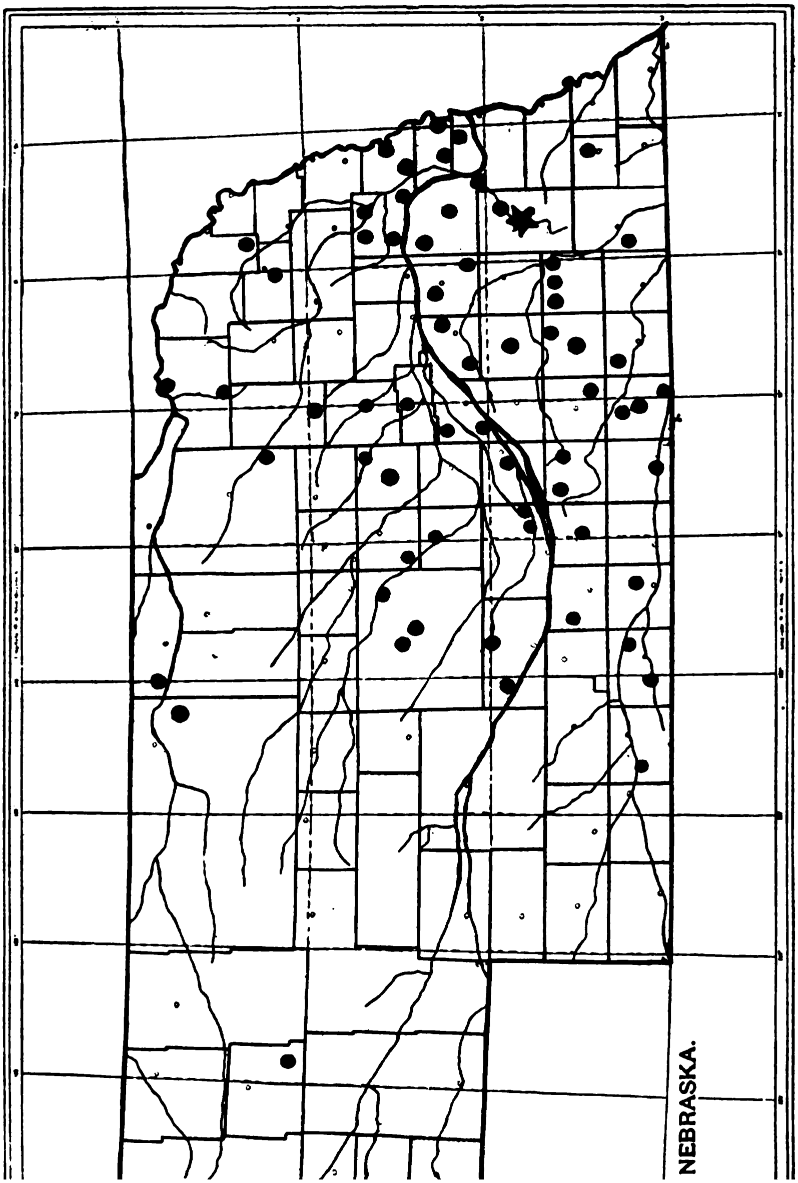


Map of the state showing the distribution of the cedar rust for three years.

PLATE I.

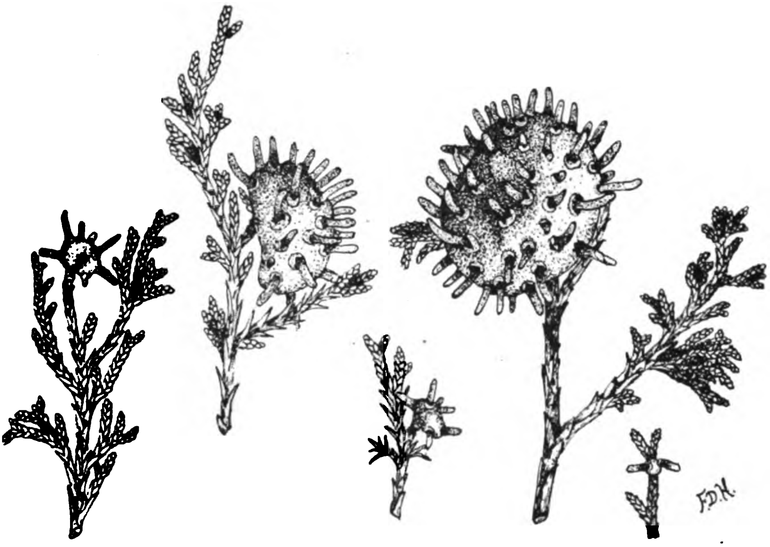
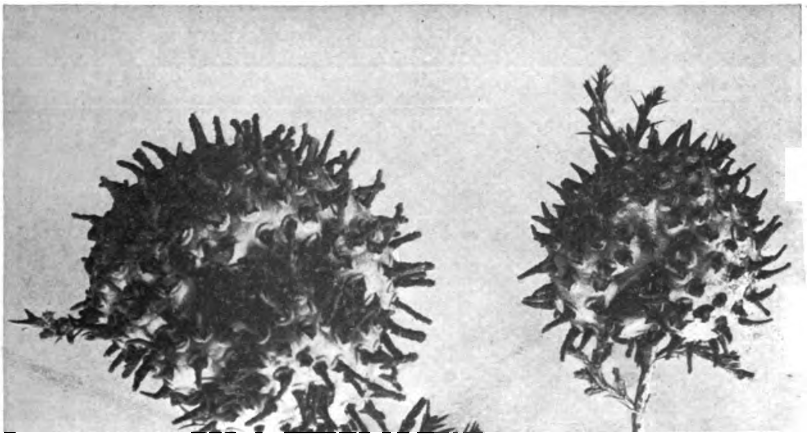
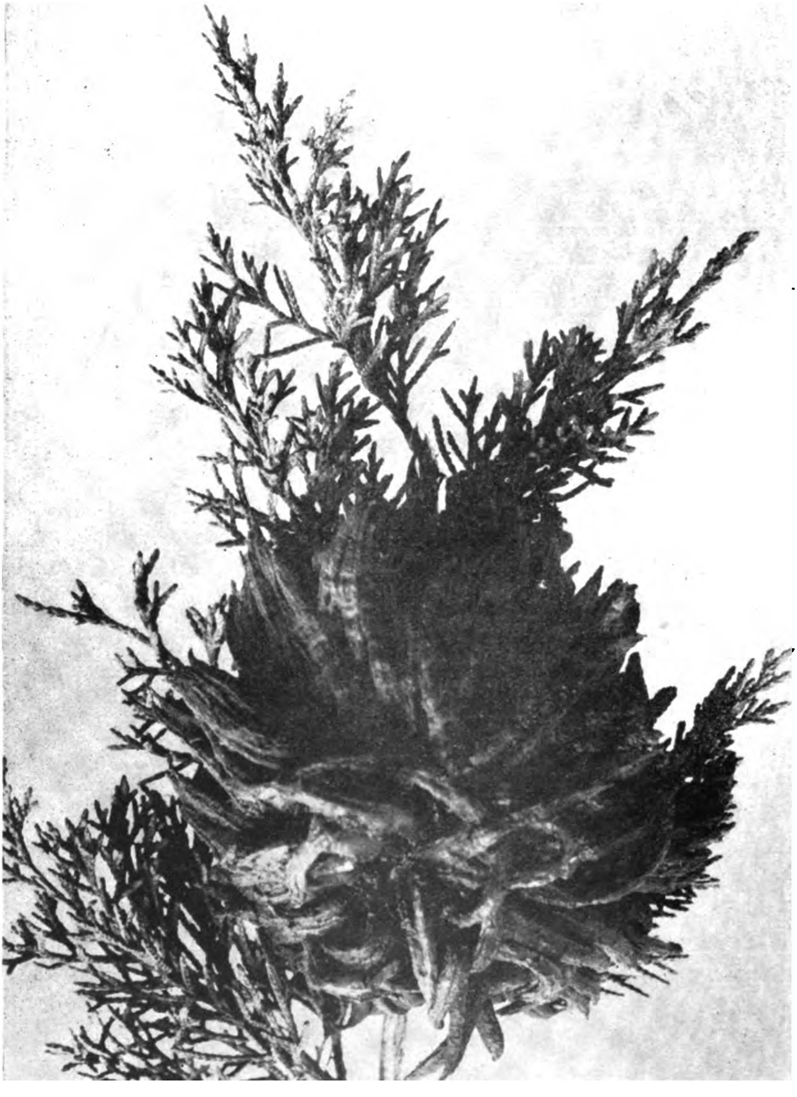


Fig. 1. "Cedar apples" of various sizes just beginning to show telia. Natural size. Drawn from a photograph.





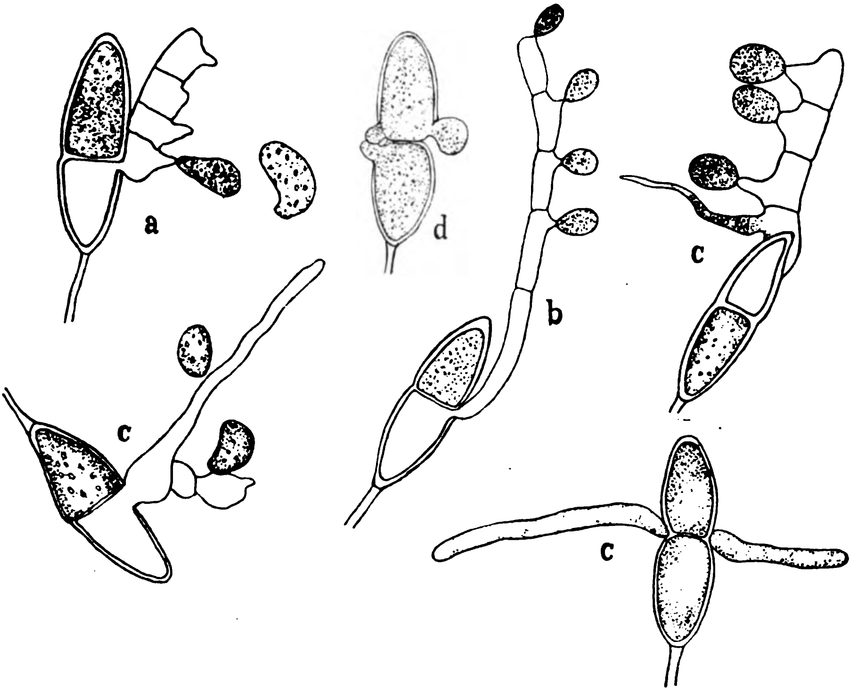


Fig. 4. Germination of teliospores. (a) typical germination, compact form; (b) typical germination, elongated type; (c) Promycelium showing variation; (d) teliospore showing sporidia produced direct.

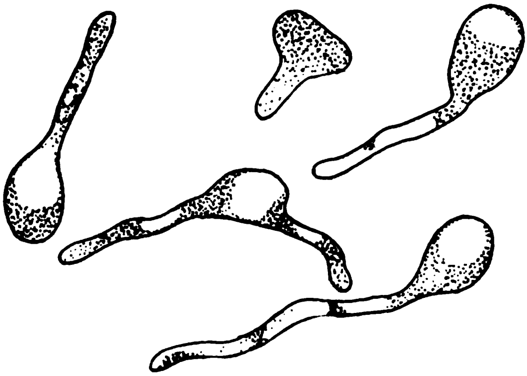


Fig. 5. Germination of sporidia.

PLATE V.

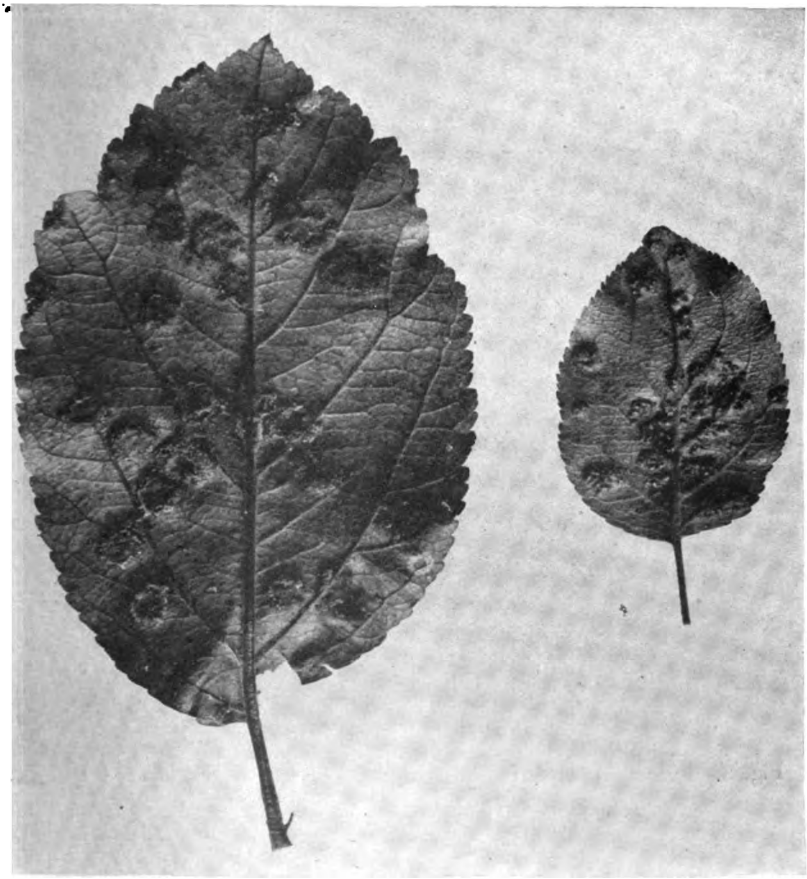
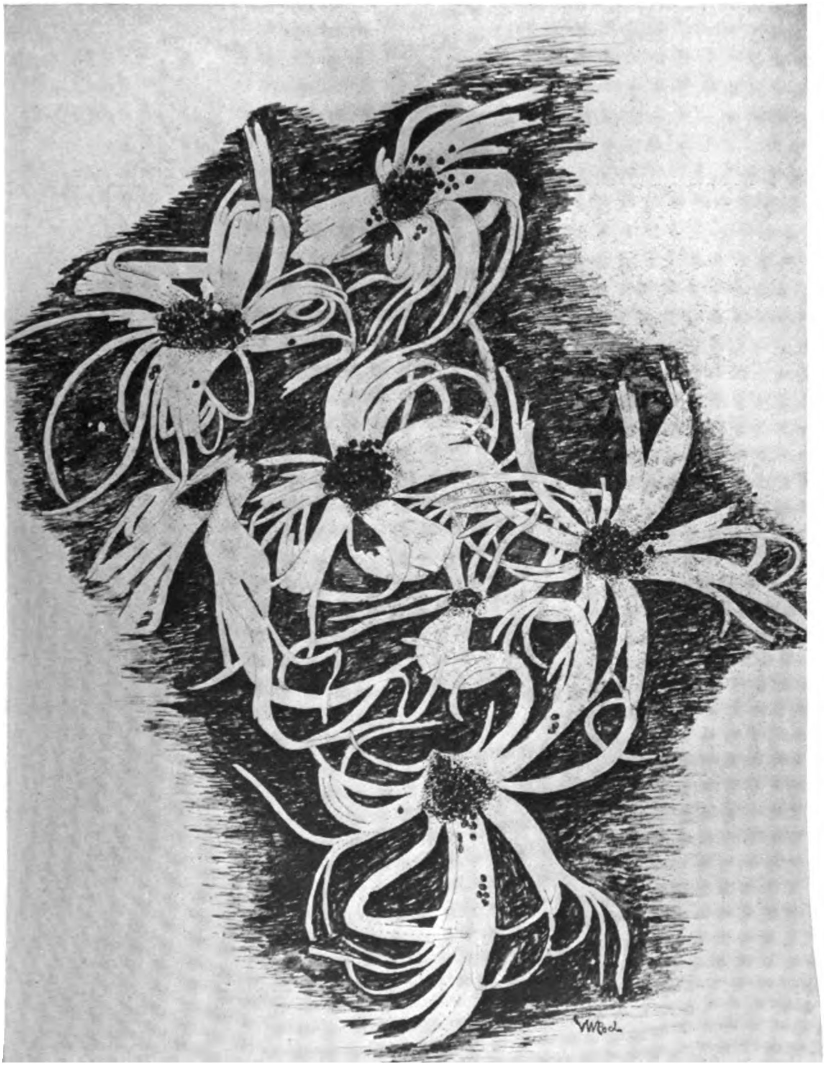


Fig. 7. Mature aecia, under surface of leaf

PLATE VII.



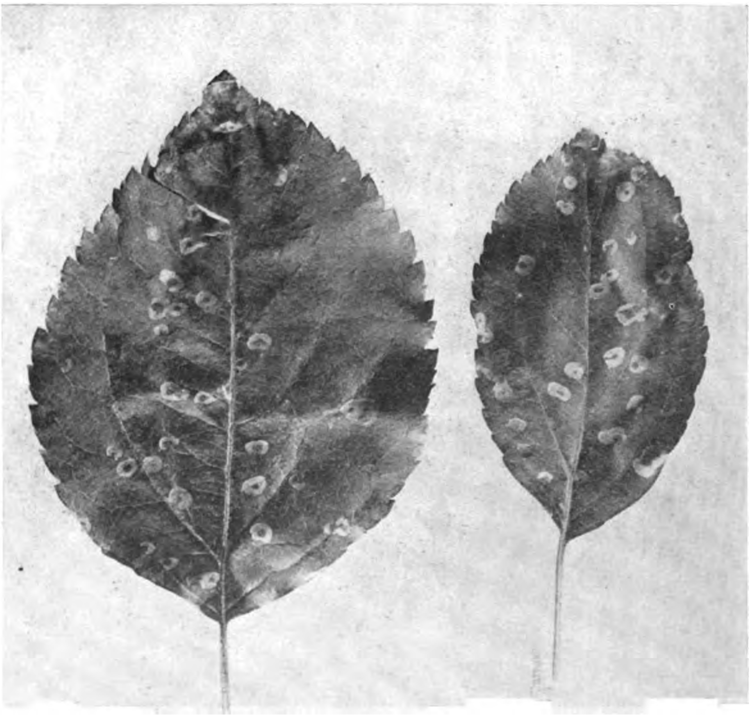


Fig. 10. Leaves showing aborted Phyllosticta-like infections.

PLATE XI

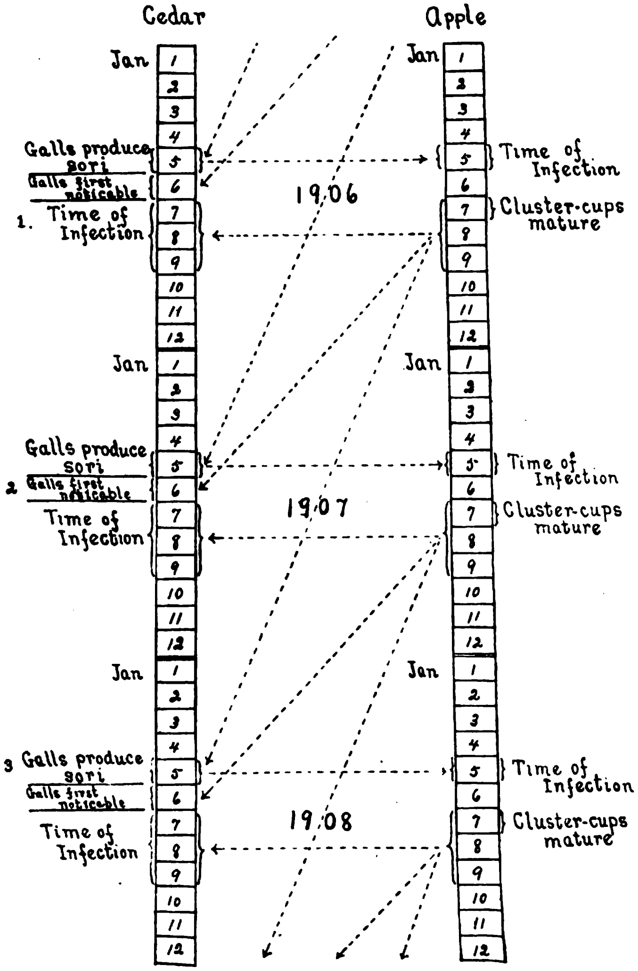
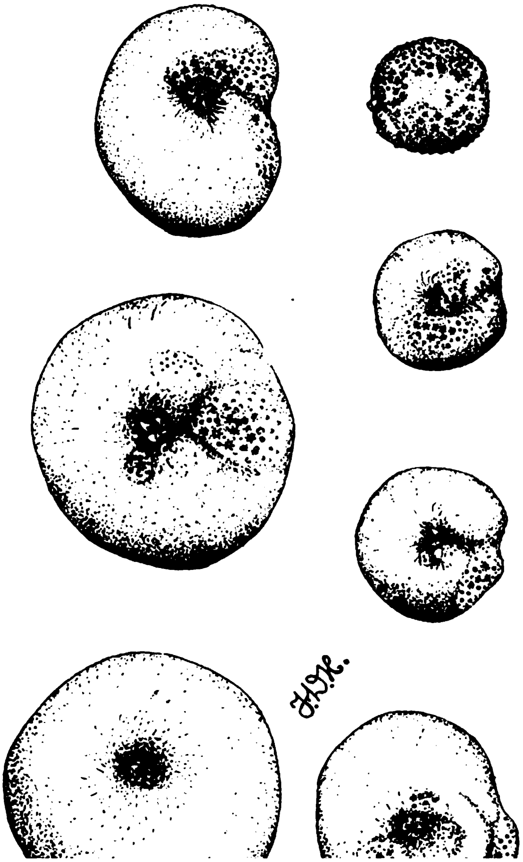

Cedar
Apple
Jan
1
2
3
4
5
6
7
8
9
10
11
12
Galls produce sori
Galls first noticeable
1. Time of Infection
Time of Infection
Cluster-cups mature
1906
Jan
Galls produce sori
2 Galls first noticeable
Time of Infection
Time of Infection
Cluster-cups mature
1907
Jan
3 Galls produce sori
Galls first noticeable
Time of Infection
Time of Infection
Cluster-cups mature
1908

PLATE XII.



THE INFLUENCE OF CHEMICAL STIMULATION UPON THE PRODUCTION OF PERITHECIA BY *MELANOSPORA PAMPEANA* SPEG.

BY F. D. HEALD* AND VENUS W. POOL.

It has been shown in several cases that the products of metabolism of one fungus may promote the formation of perithecia of another fungus. Further investigation will no doubt reveal other cases of the same sort of chemical stimulation. The present account describes the interesting relationship found to exist between *Melanospora pampeana* and certain other fungi. This fungus was first isolated in connection with the investigation of the fungi connected with "moldy" corn.

The perfect fruits of this fungus were first found growing upon and among the hyphae of *Fusarium moniliforme* which had recently infected an immature ear of corn. Saccardo[3] gives a description of what is evidently this same *Fusarium* which is reported as growing and producing catenulate conidia upon the outside of the perithecium of *Melanospora.*

Cultures of this *Fusarium* were readily secured which remained apparently pure for a week or ten days. At the end of this time, however, the typical long-necked perithecia of *Melanospora* appeared in abundance. By the use of the poured-plate method cultures of the *Fusarium* were secured in which the perithecia did not appear. Altho this was repeated several times no growth of *Melanospora* appeared in the poured-plate cultures and yet the ascospores were known to germinate readily in a hanging drop culture. The explanation of this phenomenon is evident from the facts which follow.

After repeated effort one ascospore was secured which, upon being transferred to a culture tube of ordinary culture medium, slowly produced a scanty, scarcely distinguishable, white mycelium. From this other cultures were secured but in none of these were conidia or perithecia ever produced. But when this sterile mycelium was placed in the same tube with *Fusarium moniliforme*, perithecia were produced in abundance. When *Fusarium moniliforme* was replaced by *Basisporium gallarum*, perithecia were developed in even greater abundance. Two other undetermined species of *Fusarium* were employed in the same manner, one of which caused perithecial development while the other showed no such effect. *Fusarium culmorum* caused a scanty production of perithecia.

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*Resigned September 1, 1908.

Careful examination of the hanging drop cultures of *Fusarium* and *Melanospora* growing together failed to reveal any attachment between the two such as was described by DeBary[1] for a related species, *Melanospora parasitica.* DeBary says: "The almost cylindrical brown-walled spore, which is 5-6 microns in length, germinated by the emission of a germ-tube at each extremity, the tubes, whether grown in water or in nutrient solutions, being scarcely longer than the transverse diameter of the spore. If the spore lies against or on a hypha of *Isaria*, which is most frequently the case in a state of nature, the germ-tube becomes firmly attached to the hypha of the host and then develops into a mycelium. If the germ-tube comes into contact with an older hypha of *Melanospora*, the membrane which separates them is dissolved and they coalesce with one another. But if a germinating spore lies at some distance from a growing hypha of *Isaria*, and it is not difficult to procure this in plants grown on a microscopic slide, the direction of its growth in length is deflected towards the spore till it comes in contact with the germ-tube, which then unites with it and begins to develop. The greatest distance at which the germinating spore can influence the direction of growth of the hypha is from four to five times the length of the spore."

Since the stimulus for the formation of perithecia did not come from any such attachment as DeBary describes, it is evident that the chemical composition of the medium upon which the *Fusarium* had grown is the source of the stimulus. That this is the correct explanation was shown as follows: The mycelial growth produced by *Basisporium gallarum* and of *Fusarium moniliforme* in two, three, four and six weeks upon ordinary glucose agar was removed and the medium sterilized at 110° C.

These media were then inoculated with the sterile mycelium of *Melanospora* which had been obtained from the ascospore *mycelium.* This was repeated several times with the result that if a very old culture of *Fusarium* or *Basisporium* was used the formation of perithecia was entirely inhibited. If younger cultures were used the perithecia were formed in four to seven days. The medium from a two-weeks' old culture of *Basisporium* had the greatest stimulating effect upon the sterile *Melanospora* mycelium. In older cultures, instead of this effect being stimulating it gradually became poisonous until it inhibited the growth of the fungus.

A careful titration of the medium when first made and after the mycelia of *F. moniliforme* and *B. gallarum* were removed showed that the acidity was much increased. A superficial chemical analysis showed the presence of some very complex organic acid. It is therefore evident that for the development of its perithecia *Melanospora* requires certain chemical compounds which are regularly produced by *F. moniliforme* and *B. gallarum* and possibly by other fungi.

Molliard[2] has described a similar case in a species of *Ascobolus.* In pure cultures this fungus produced only imperfect perithecia and then only after considerable time, but if bacteria were present the perithecia were produced in abundance after 10-15 days.

The senior author has recently found that the fungus known as *Sordaria longicaudata* produces an abundance of perithecia following a copious growth of *Pilobolus* on horse manure, but this same *Sordaria* always fails to produce perithecia upon sterilized compost which has not previously borne a crop of *Pilobolus.*

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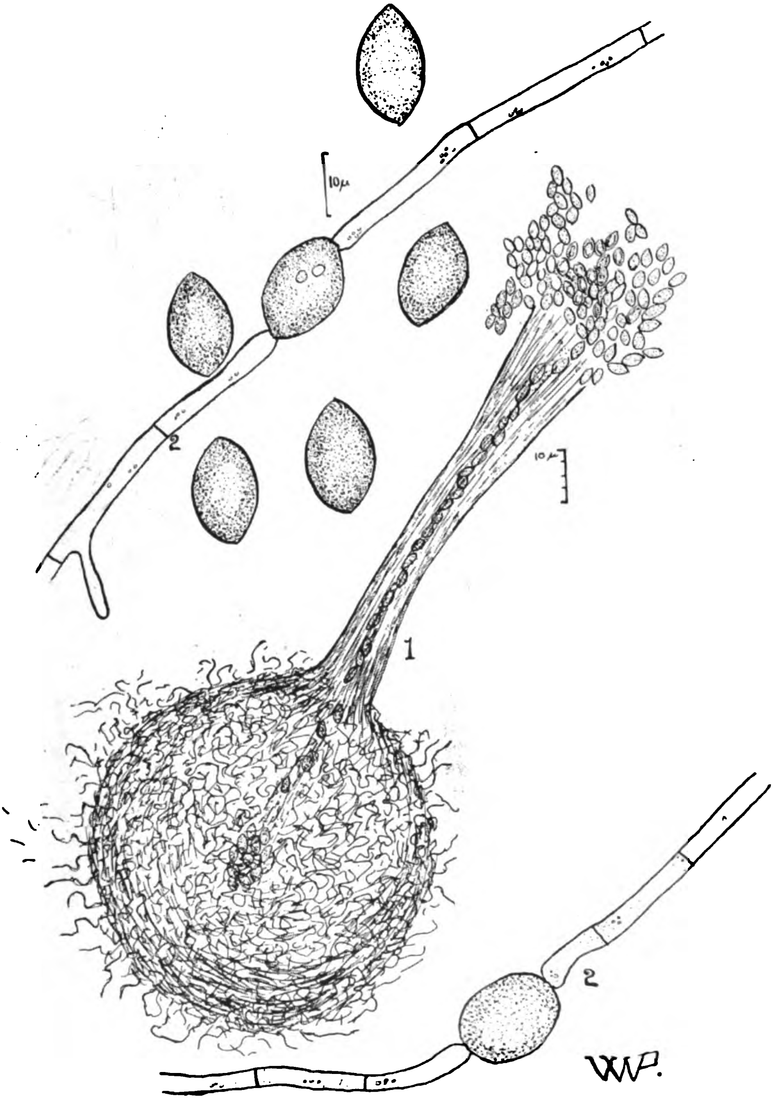
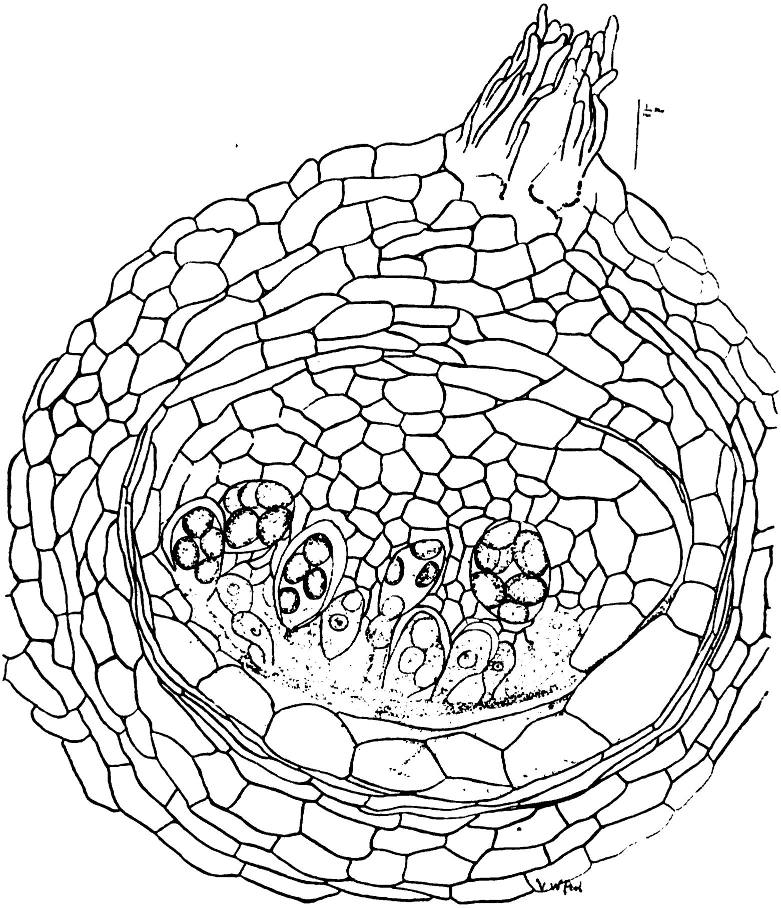

10μ
10μ
1
2
2
W.W.P.

PLATE II.



DISSEMINATION OF TUBERCULOSIS BY THE MANURE OF INFECTED CATTLE.

By A. T. Peters and Clarence Emerson.

DISSEMINATION OF TUBERCULOSIS BY THE MANURE OF INFECTED CATTLE.

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INTRODUCTION.

Schroeder and Cotton by their work published in Bulletin No. 99 of the Bureau of Animal Industry, on "The Danger from Tuberculous Bacilli in the Environment of Tuberculous Cattle," have aroused considerable interest in this subject. Their conclusions indicate that one of the commonest paths of egress for the tubercle bacillus from the bodies of infected cattle is the intestinal tract, and that bacilli are passed thru the intestines and still retain their virulence. They ascribe to the feces of tuberculous cattle a place similar to that accorded to the sputa of tuberculous persons. The report of the Chief of the Bureau of Animal Industry for 1907 says: "The work of the year demonstrated that the commonest mode for the discharge of tubercle bacilli from the bodies of tuberculous cows is with their feces, that about 40 per cent of the tuberculous cows that show *no symptoms of disease* are expelling and scattering tubercle bacilli, and that tubercle bacilli passed with the feces of tuberculous cows are actively pathogenic."[1] If 40 per cent of those which show no symptoms of disease are passing virulent tubercle bacilli, the per cent, without much doubt, will be greater if the visibly tuberculous cows are included. These results are indeed striking, since, if definitely established, we shall have to deal with a problem which is of far-reaching importance, important because fecal contamination of milk would offer a means of frequent occurrence of tubercle bacilli in dairy products, and deserving of exceptional consideration because hogs are commonly permitted to run in the same pasture and feed lots with cattle and since, being very susceptible to infection by this organizm, its presence in cow manure would be a constant source of danger to them.

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*Clarence Emerson, Ph. D., Assistant in Animal Pathology.

Schroeder and Cotton[2] examined seven samples of feces from cows affected with tuberculosis. They claim to have found, by microscopic examination, tubercle bacilli in five of these samples, or 71.43 per cent. Inoculation and ingestion experiments were made with the feces of four of the cattle, with the result that three were shown to be passing virulent bacilli.

Reynolds and Beebe[3] made a larger number of examinations, having had 45 animals under experiment. Some of them were tested from three to five times for virulent bacilli in the feces. Their results differ considerably from those of Schroeder and Cotton since they were able to demonstrate virulent bacilli in the feces of only one cow and this one was badly affected with tuberculosis, the bacilli being constantly present in the nasal secretion.

Schroeder and Mohler[4] have demonstrated the ability of the tubercle bacillus to pass thru the intestinal tract and retain its virulence. This was shown by feeding healthy cattle a culture of virulent tubercle bacilli. The manure from these cattle was given to an experimental pen of four hogs. Three out of the four became infected with the disease.

DEMONSTRATION OF TUBERCLE BACILLI IN THE FECES.

It may be well at the start to mention a few important things to be considered in an examination of cow feces for the tubercle bacillus. In the first place it should be borne in mind that a *microscopic examination alone is of little value.* In cow feces we frequently meet with morphologically similar bacilli which stain in the same way and which by means of the ordinary miscrosopic examination we are unable to differentiate from the tubercle bacillus. Besides this, tubercle bacilli might be (and the probabilities are that this is true in many cases) present in such small numbers that a microscopic examination would be inadequate to disclose them. This was true in the feces of cow No. 2½ of the Minnesota Experiment Station, in which tubercle bacilli were demonstrated by animal inoculation while repeated microscopical examinations failed to reveal them.

We must resort to animal experiment for absolute proof, and the guinea pig is the most serviceable for this purpose. Even here we cannot rely merely on the production of symptoms and nodular formations, because Rabinowitch's butter-bacillus[5] may give rise to these. The nodules should be examined for the giant cells and the histological picture which is characteristic of the tubercle noduli.

Before we can say positively that a given sample of cow feces contains virulent tubercle bacilli we must have produced in a susceptible animal the characteristic lesions of tuberculosis and must have demonstrated in these lesions the typical features of a tuberculous nodule.

Ingestion experiments with hogs might be a valuable method of demonstration were it not for the frequency of the natural infection in these animals. Schroeder and Cotton have shown that hogs readily take the disease when fed with infected material, and if we could be certain that they are free from disease before the experiment, their use for this purpose would be advisable. The application of the tuberculin test must then be resorted to before utilizing a hog for this purpose.

THE INVESTIGATION.

The cows utilized in this experiment, forty-one in number, were for the most part from a single large dairy herd in which over 80 per cent had reacted to the tuberculin test. The majority of these were in excellent condition, the fact that they were suffering from the disease being indicated only by the tuberculin test. Four of the forty-one included two dairy cows and two males at the Nebraska Experiment Station. In all cases the tuberculin test had been applied only a few weeks before making the examination.

METHOD OF INVESTIGATION.

The feces were taken from the rectum by means of a rectal spoon. This was inserted several inches into the rectum and rotated as it was withdrawn. Difficulty in obtaining sufficient material was very seldom encountered.

The investigation included a microscopic examination of stained spreads of the material and animal inoculations. No attempt was made to determine the presence of the tubercle bacillus by the microscope, believing this to be impossible.

For inoculation of guinea-pigs the manure was suspended in water and about .5 to 1 cc. injected. The guinea-pigs succumbed to the action of toxic substance or septicaemia in only a few instances.

RESULTS OF THE INVESTIGATION.

The results of this investigation are indicated in the following table. It will be seen that in twenty-two out of forty-one samples of manure, acid-fast bacilli morphologically similar to the tubercle bacillus were demonstrated by the microscope. Subsequent inoculation tests showed that of these twenty-two samples only three (7.31 per cent of the forty-one samples) were passing virulent tubercle bacilli. This brings out the fact before mentioned, that a microscopic examination is untrustworthy in demonstrating tubercle bacilli in cow manure.

Of the three which were passing virulent tubercle bacilli in their feces, two were in good physical condition and from their appearance the disease would not have been suspected. The third, cow No. 102, was poor but the symptoms of the disease were not marked. The number of acid-fast bacilli in her feces, as revealed by the microscope, was exceedingly large. In every field a number of them could be located, and in one place an area of degenerating tissue with many bacilli clinging to it was found.

The appearance of cow No. 20 was such as to arouse no suspicion of tuberculosis. Her feces contained fairly large numbers of acid-fast rods, some of which were virulent tubercle bacilli.

No. 204 is of special interest because of his exceptionally fine appearance. This is a large Aberdeen Angus bull, remarkably fat and sleek. He, however, suffers a persistent but moderate cough and was passing virulent tubercle bacilli in his feces.

In the face of this evidence we cannot disregard a possible danger from cow manure even tho the appearance of the animal is excellent.

It will be noted that only those samples of manure in which acid-fast bacilli were demonstrated microscopically were utilized in inoculation experiments. The probabilities are that some of those in which the microscope did not reveal acid-fast bacilli contained virulent germs of tuberculosis. The one positive case at the Minnesota Experiment Station was constantly negative to microscopic examination.

A temporary scarcity of guinea-pigs necessitated the selection of those samples in which the presence of the germ was considered most probable.

APPEARANCE OF COWS WHICH ARE PASSING VIRULENT TUBERCLE BACILLI.

According to Schroeder and Cotton, cows which are apparently in good physical condition and show no marked symptoms of infection may scatter virulent bacilli in their feces. They explain this by the fact that cows, instead of expectorating, swallow their sputum, and the bacilli being able to preserve their lives and virulence during a passage thru the intestinal tract are excreted without having lost the power of infecting other animals. This reasoning appears logical and is substantiated by their results and by the work of the Nebraska Experiment Station.

Many cases of tuberculosis in cattle may exist in which tubercle bacilli do not appear in the feces or in any part of the intestinal tract. Their excretion in this way is not due to a localization of the disease in the intestinal tract for, quoting from Schroeder and Cotton, "It must not be supposed that the occurrence of the bacilli in the feces of cattle affected with naturally acquired tuberculosis is due to an intestinal disease, as tuberculosis of the intestinal mucosa of cattle is an extremely rare affection."

The presence of tubercle bacilli in the intestines is the result of a communication between a tuberculous focus and the intestinal tract. This might be due in some cases to a sinus from a sloughing gland but it is due in most instances to the swallowing of necrotic, or diseased, tissue eliminated from the lungs. It is the general opinion that in all animals the lungs are by far the most frequent organs affected. It is therefore to be expected that at some stage of the infection most of the reacting cattle will be eliminating and swallowing material which contains the germ.

Cows which harbor extensive tuberculous foci and present a chronic cough of severe grade may still retain a fat, sleek appearance. Altho animals which present visible signs of the disease are more apt to have the virulent germs in their manure, we shall, nevertheless, have to suspect every cow which reacts to the tuberculin test.

CONCLUSIONS.

1. Tubercle bacilli may pass thru the intestinal tract of cattle and retain their virulence.

2. Tubercle bacilli in the feces of cattle may readily contaminate dairy products and cause infection in hogs.

3. Animal inoculation and a microscopical examination of the lesions produced are necessary to definitely establish the presence of tubercle bacilli in cow feces.

4. Ingestion experiments with hogs, previously proven to be free from the disease by application of the tuberculin test, are valuable means of demonstrating tubercle bacilli in the manure of cattle.

5. Hogs should not be permitted to run in the same pens with cattle, especially if the latter are known to be tuberculous.

6. Dairy products from tuberculous cows, even tho there is no infection of the udder, are a source of danger to man.

7. The number of tuberculous cows which show no symptoms of disease but which excrete virulent tubercle bacilli in their manure is sufficiently large to make this an important factor in the control of tuberculosis.

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2. Bureau of Animal Industry Bulletin No. 99.
3. Minnesota Experiment Station Bulletin No. 103.
4. Bureau of Animal Industry Bulletin No. 88.

Table demonstrating the results of tubercle bacilli in the feces of cows.

Cow No.	Condition of cow	Reacted to tuberculin test	Feces examined. Date, 1908.	Acid-fast bacilli present: + = yes, — = no.	Result of guinea pig inoculation: + = infection, — = no infection.	Milk examined–Date.	Acid-fast bacilli present: + = yes, — = no.	**Result of guinea pig inoculation: + = infection, — = no infection.**
6	good	....	Nov. 9	—	omitted	Nov. 9	—	—
54	good	....	Nov. 9	—	—	Nov. 9	—	—
95	poor	....	Nov. 10	—	—	Nov. 10	—	—
5	good	....	Nov. 10	—	—	Nov. 10	—	—
19	good	....	Nov. 10	—	—	Nov. 10	—	—
98	poor	....	Nov. 10	—	—	Nov. 10	—	—
60	good	....	Nov. 10	—	—	Nov. 10	—	—
87	good	....	Nov. 10	—	—	Nov. 10	—	—
96	good	....	Nov. 11	—	—	Nov. 11	—	—
48	good	....	Nov. 11	—	—	Nov. 11	—	—
28	good	....	Nov. 11	—	—	Nov. 11	—	—
14	good	....	Nov. 11	—	—	Nov. 11	—	—
23	good	....	Nov. 11	—	—	Nov. 11	—	—
11	good	....	Nov. 11	—	—	Nov. 11	—	—
15	good	....	Nov 11	—	—	Nov. 11	—	—
24	good	....	Nov. 14	—	—	Nov. 14	—	—
17	good	....	Nov. 14	—	—	Nov. 14	—	—
3	good	....	Nov. 14	—	—	Nov. 14	—	—
2	good	....	Nov. 14	—	omitted	Nov. 14	—	omitted
38	good	....	Nov. 14	+	—	Nov. 14	—	—
22	poor	....	Nov. 14	+	—	Nov. 14	—	—
26	good	....	Nov. 14	+	—	Nov. 14	—	—
102	poor	....	Nov. 14	+	+	Nov. 14	—	—
13	good	....	Nov. 14	+	—	Nov. 14	—	—
27	good	....	Nov. 17	+	—	Nov. 17	—	—
12	good	....	Nov. 17	+	—	Nov. 17	—	—
16	good	....	Nov. 17	+	—	Nov. 17	—	—
20	good	....	Nov. 17	+	+	Nov. 17	—	—
101	poor	....	Nov. 17	+	—	Nov. 17	—	—
1	good	....	Nov. 19	+	—	Nov. 19	—	—
50	good	....	Nov. 19	+	—	Nov. 19	—	—
58	good	....	Nov. 19	+	—	Nov. 19	—	—
43	good	....	Nov. 19	+	—	Nov. 19	—	—
47	good	....	Nov. 25	+	—	Nov. 25	—	—
8	good	....	Nov. 25	+	—	Nov. 25	—	—

SECOND REPORT OF THE NEBRASKA SEED LABORATORY

BY

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Collaborator in Charge,
AND
MISS NELLE STEVENSON, A. B., LABORATORY AID,
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INTRODUCTION.

This report presents the more technical results secured by the Nebraska Seed Laboratory during the second year of its operation, covering the fiscal year from July 1, 1908, to July 1, 1909. During this year, as will be seen by reference to Table II, the work of the Laboratory has increased about 50 per cent over the preceding year* and while, as before, about half of the samples were received from Nebraska farmers and seedsmen, yet samples were received from thirteen states in all. It is evident that the work of the Laboratory is commanding more and more of the attention and appreciation of all persons interested in either the growth, sale, or use of agricultural seeds. The following tables are self-explanatory and present the more important results secured.

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*WILCOX, E. M. AND STEVENSON, N.
1909 Report of the Nebraska Seed Laboratory. Bul. Nebr. Exp. Sta. **110**: 1-29. Fig. 1-12. This report includes a more popular account of the first year's work together with illustrations and descriptions of some of the more common weed seeds.

TABLE I.—*General summary of the two years' work, showing also the geographical source of the samples.*

State	No. of samples		Identification		Examination		Purity		Germination		Total No. of tests	
	1908	1909	1908	1909	1908	1909	1908	1909	1908	1909	1908	1909
Colorado	45	36	0	0	0	0	32	3	30	36	62	39
District of Columbia	0	11	0	0	0	0	0	11	0	11	0	22
Illinois	0	5	0	0	0	0	0	4	0	3	0	7
Iowa	68	129	0	7	0	1	64	108	18	94	82	210
Kansas	5	9	0	0	0	0	5	9	5	9	10	18
Minnesota	59	21	1	3	0	0	59	18	33	18	93	39
Missouri	0	7	0	0	0	0	0	7	0	6	0	13
Montana	3	3	0	0	1	2	2	1	0	1	3	4
Nebraska	246	396	10	27	26	7	180	300	122	275	338	609
New York	15	43	0	0	0	0	3	18	15	36	18	54
South Carolina	0	1	0	0	0	0	0	1	0	1	0	2
South Dakota	16	39	0	1	2	1	14	37	7	23	23	62
Utah	6	0	0	0	0	0	5	0	2	0	7	0
Wisconsin	0	1	0	0	0	0	0	1	0	1	0	2
Totals	463	701	11	38	29	11	364	518	232	514	636	1081
	1164		49		40		882		746		1717	

II.—Showing results of tests and examinations of samples of various agricultural seeds received from July 1, 1908, to July 1, 1909.

ind of seed	Total number of samples received	Number of samples for				Results of tests of samples											
						Purity test									Germination test		
						Pure seed			Inert matter			Foreign seed					
		Identification	Examination	Purity	Germination	Highest %	Lowest %	Average %	Highest %	Lowest %	Average %	Highest %	Lowest %	Average %	Highest %	Lowest %	Average %
n sp.	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
alba—Redtop	13	1	....	12	12	97.33	13.11	62.00	86.0	2.17	38.01	10.0	0.50	2.69	93	4	55
epa—Onion	8	....	....	....	8	....	....	....	....	....	....	....	....	....	97	56	77
on sorghum — Sor-	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	73
um sp.—Snap-	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	84
raveolens—Celery	2	....	....	....	2	....	....	....	....	....	....	....	....	....	69	27	52
etroselinum— y	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	59
tiva—Oats	4	....	....	....	4	....	....	....	....	....	....	....	....	....	97	95	96
aris—Beets	4	....	....	....	4	....	....	....	....	....	....	....	....	....	88	48	70
napus—Rape	1	....	....	1	1	....	....	96.6	....	....	3.41	....	....	0	....	....	86
oleracea—Cabbage	9	....	....	....	9	....	....	....	....	....	....	....	....	....	95	45	65
rapa—Turnip	2	....	....	....	2	....	....	....	....	....	....	....	....	....	95	57	76
inermis—Awnless grass	11	1	....	10	10	92.7	28.1	77.1	31.4	5.24	17.8	62.5	0.66	5.04	93	5	51
ecalinus—Cheat	5	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
sativa—Large false flax	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
n annuum—Pepper	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	65
a repens	4	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Kind of Seed	Total number of samples received	Number of samples for				Results of tests of samples											
						Purity test									Germination test		
						Pure seed			Inert matter			Foreign seed					
		Identification	Examination	Purity	Germination	Highest %	Lowest %	Average %	Highest %	Lowest %	Average —	Highest %	Lowest %	Average %	Highest %	Lowest %	Average %
Cichorium endivum—Endive	1				1												28
Citrullus citrullus—Citron	2				2										36	0	18
Citrullus citrullus—Watermelon	6				6										76	53	61
Convolvulus arvensis—Field bindweed	1	1															
Cucumis melo—Muskmelon	6				6										89	68	81
Cucumis sativus—Cucumber	17				17										92	13	60
Cucurbita pepo—Pumpkin	1				1												81
Cucurbita pepo—Squash	5				5										84	34	56
Cuscuta arvensis—Field dodder	1	1															
Dactylis glomerata—Orchard grass	5			5	5	75.5	47.1	61.3	39.7	18.1	23.7	34.8	1.05	19.0			
Daucus carota—Carrot	1				1												45
Desmanthus illinoensis—Illinois mimosa	1	1															
Echinochloa crus-galli—Barnyard grass	1	1															

a elatior pratensis—dow fescue	23			23	21	99.4	90.7	96.6	10.5	0.43	2.45	3.69	0.1	0.9	93	0	62
um vulgare—Barley	3				3										98	36	77
a sativa—Lettuce	2				2										97	88	93
usitatissimum—Flax	2		2		2										98	97	97
perenne—English rass	2			2	2	98.5	97.8	98.1	0.26	0.10	0.18	2.11	1.27	1.69	81	10	46
americanus	1	1															
rsicum lycopersicum—ato	5				5										81	0	52
ugo sativa—Alfalfa	249		7	240	177	99.9	37.6	92.5	16.0	0.09	2.71	51.6	0	4.56	98	10	72
e—Grass	3		1	2		70.7	68.8	69.8	28.9	28.7	28.8	2.26	0.59	1.43			
e—Timothy and Al- clover	2			2		97.4	89.6	93.5	2.18	1.49	1.84	8.96	0.45	4.71			
e—Weed	9	8		1				3.09			94.9			1.99			
aca sativa—Parsnip	3				3										82	18	57
lus vulgaris—Bean	5				5										98	90	92
n pratense—Timothy	37		1	35	24	99.9	70.2	91.4	26.0	0.05	13.4	9.07	0	1.56	100	85	95
sp.—Fir	2	2															
sativum—Peas	6				6										97	86	94
go lanceolata—Buck-	2	2															
pratensis—Kentucky -grass	23			23	15	82.4	0.84	69.9	42.3	17.5	25.7	77.7	0.10	4.38	88	25	56
num convolvulus—lweed	1	1															
nus sativus—Radish	6				6										100	85	94
rhaponticum—Rhu-	1				1												81
acetosella—Sheep el	1	1															
la kali-tenuifolia—Rus- n thistle	1	1															
aria vaccaria—Cow b	1	1															
a italica—German mil-	2			2		97.3	95.6	96.5	2.23	0.81	1.52	2.13	1.90	2.02			

Kind of Seed	Total number of samples received	Number of samples for				Results of tests of samples											
						Purity test									Germination test		
						Pure seed			Inert matter			Foreign seed					
		Identification	Examination	Purity	Germination	Highest %	Lowest %	Average %	Highest %	Lowest %	Average —	Highest %	Lowest %	Average %	Highest %	Lowest %	Average —
Setaria viridis—Green fox-tail	1	1															
Spinacea oleracea—Spinach	2				2										59	54	57
Sporobolus sp.	1	1															
Tragopogon porrifolius—Salsify	1				1												80
Trifolium hybridum—Alsike clover	17			17	14	98.7	58.0	85.3	3.54	0.40	1.23	40.3	0.60	13.5	86	55	77
Trifolium pratense—Red clover	138			136	96	99.7	59.9	94.1	35.7	0.22	2.90	74.9	0	2.99	96	14	82
Trifolium repens—White clover	7			7	6	97.4	87.4	94.7	0.94	0.15	0.55	11.6	0.65	4.74	87	46	64
Verbena sp	1	1															
Viola tricolor—Pansy	1				1												83
Vicia villosa—Winter vetch	1	1															
Zea mays—Corn	22				22										100	91	98
Total	701	38	11	518	514												

TABLE III.—*Kinds of weed seeds found in alfalfa seed.*

SCIENTIFIC NAME	COMMON NAME	NO. OF SAMPLES IN WHICH FOUND
Setaria viridis	Green foxtail	151
Salsola kali-tenuifolia	Russian thistle	75
Chenopodium album	Lamb's-quarters	72
Amaranthus sp	Amaranth	60
Plantago lanceolata	Buckhorn	56
Melilotus alba	Sweet clover	51
Setaria glauca	Yellow foxtail	47
Centaurea repens		44
Panicum capillare	Old-witch grass	39
Echinochloa crus-galli	Barnyard grass	36
Chenopodium fremontii	Fremont's goosefoot	35
Eruca sativa	Rocquette	35
Cichorium intybus	Wild chicory	32
Sporobolus sp		28
Polygonum sp		25
Polygonum aviculare		23
Cenchrus carolinianus	Sandbur	17
Eragrostis sp		17
Medicago lupulina	Yellow trefoil	16
Rumex crispus	Curled dock	15
Daucus carota	Wild carrot	15
Cuscuta planiflora	Small-seeded alfalfa dodder	14
Ambrosia artemisiifolia	Ragweed	14
Cuscuta epithymum	Clover dodder	13
Panicum dichotomiflorum	Spreading panicum	13
Cuscuta arvensis	Field dodder	12
Gramineae sp	Grasses	11
Brassica juncea	Chinese mustard	11
Polygonum convolvulus	Wild buckwheat	11
Undetermined		11
Labiatae sp		10
Solanum sp		10
Malva rotundifolia	Common mallow	10
Grindelia squarrosa	Gumweed	9
Helianthus annuus	Wild sunflower	9
Melilotus indica	Small flowered melilot	8
Muhlenbergia sp		7
Amaranthus blitoides	Spreading amaranth	7
Lotus corniculatus	Bird's foot trefoil	7
Iva axillaris	Poverty weed	6
Trifolium suaveolens	Shaftel	6
Centaurea sp		6
Cuscuta indecora	Large-seeded alfalfa dodder	5
Leguminosae sp		5
Polygonum persicaria	Lady's thumb	5
Sporobolus asper	Rough rush grass	5
Silene dichotoma	Forked catch-fly	5
Lappula redowskii occidentalis	Hairy stickseed	4
Agropyron sp		4
Compositae sp		4
Silene noctiflora	Night flowering catch-fly	4
Atriplex sp		4
Saponaria vaccaria	Cow herb	4
Lepidium draba	Hoary cress	4

SCIENTIFIC NAME	COMMON NAME	NO. OF SAMPLES IN WHICH FOUND
Chenopodium murale	Nettle-leaved goosefoot	4
Digitaria sanguinalis	Large crab-grass	4
Plantago aristata	Bracted plantain	3
Plantago rugelii	Black-seeded plantain	3
Digitaria humifusa	Small crab grass	3
Picris echioides	Ox-tongue	3
Prunella vulgaris	Heal-all	3
Lepidium campestre	Field cress	3
Verbena stricta	Hoary vervain	2
Verbena hastata	Blue vervain	2
Euphorbia preslii	Spurge	2
Lepidium apetalum.	Apetalous pepper-grass	2
Sida spinosa	Spiny sida	2
Trifolium sp		2
Rumex acetosella	Sheep sorrel	2
Eragrostis abyssinica	Teff	2
Verbena officinalis	European vervain	2
Umbelliferae sp		2
Trigonella sp		2
Rumex obtusifolius	Bitter dock	1
Solanum rostratum	Buffalo bur	1
Picris hieracioides	Hawkweed picris	1
Crepis capillaris	Smooth hawk's beard	1
Convolvulus arvensis	Field bindweed	1
Juncus sp		1
Panicum virgatum	Switch grass	1
Anthyllis vulneraria	Kidney vetch	1
Euphorbia maculata	Milk purslane	1
Sherardia arvense	Blue field-madder	1
Datura sp		1
Rosaceae sp		1
Polygonum sagittatum	Arrow-leaved tear thumb	1
Conium maculatum	Poison hemlock	1
Verbena urticaefolia	White vervain	1
Thlaspi arvense	Field penny cress	1
Acalypha virginica	Three-seeded mercury	1
Torilis nodosa	Knotted hedge-parsley	1
Brassica nigra	Black mustard	1
Cirsium lanceolatum.	Bull thistle	1
Convolvulus sp		1
Scirpus sp		1
Rudbeckia hirta	Brown-eyed susan	1
Ornithopus sp		1
Camelina sativa.	Large-seeded false flax.	1

TABLE IV.—*Kind of weed seeds found in red clover seed.*

SCIENTIFIC NAME	COMMON NAME	NO. OF SAMPLES IN WHICH FOUND
Setaria viridis	Green foxtail	113
Plantago rugelii.	Black-seeded plantain	71
Setaria glauca	Yellow foxtail	66
Rumex crispus.	Curled dock	54

SCIENTIFIC NAME	COMMON NAME	NO. OF SAMPLES IN WHICH FOUND
Digitaria humifusa	Small crab-grass	50
Polygonum persicaria	Lady's-thumb	47
Plantago lanceolata	Buckhorn	44
Chenopodium album	Lamb's-quarters	39
Panicum capillare	Old-witch grass	35
Ambrosia artemisiifolia	Ragweed	35
Echinochloa crus-galli	Barnyard grass	34
Rumex acetosella	Sheep sorrel	31
Digitaria sanguinalis	Large crab grass	25
Amaranthus sp	Amaranth	25
Solanum sp		22
Euphorbia preslii	Spurge	21
Silene noctiflora	Night-flowering catch-fly	19
Panicum dichotomiflorum	Spreading panicum	13
Daucus carota	Wild carrot	13
Sida spinosa	Spiny sida	12
Sporobolus sp		9
Gramineae sp	Grasses	9
Brassica juncea	Chinese mustard	9
Plantago aristata	Bracted plantain	9
Sporobolus asper	Rough rush grass	8
Prunella vulgaris	Heal-all	8
Brassica arvensis	Charlock	8
Verbena urticaefolia	White vervain	6
Verbena officinalis	European vervain	6
Scirpus sp		6
Chenopodium fremontii	Fremont's goose-foot	6
Acalypha virginicum	Three-seeded mercury	5
Plantago major	Plantain	5
Verbena hastata	Blue vervain	5
Eragrostis sp		5
Undetermined		4
Polygonum sp		4
Paspalum setaceum	Slender paspalum	4
Potentilla monspeliensis	Cinquefoil	3
Carex sp	Sedge	3
Polygonum aviculare	Knotweed	3
Teucrium sp		3
Oenothera biennis	Evening primrose	3
Euphorbia maculata	Milk purslane	3
Cuscuta arvensis	Field dodder	3
Salsola kali tenuifolia	Russian thistle	3
Cuscuta epithymum	Clover dodder	2
Cirsium lanceolatum	Bull thistle	2
Panicum huachucae silvicola	Woolly panicum	2
Lepidium apetalum	Apetalous peppergrass	2
Camelina sativa	Large-seeded false flax	2
Muhlenbergia sp		2
Cenchrus carolinianus	Sandbur	2
Anthyllis vulneraria	Kidney vetch	2
Anthemis cotula	May-weed	2
Atriplex sp		2
Compositae sp		1
Trifolium sp		1
Holcus lanatus	Velvet grass	1

SCIENTIFIC NAME	COMMON NAME	NO. OF SAMPLES IN WHICH FOUND
Trifolium arvensis	Rabbit's foot clover	1
Trifolium filiforme	Suckling clover	1
Linaria spuria	Round-leaved toad-flax	1
Anagallis arvensis	Red pimpernel	1
Picris echioides	Ox-tongue	1
Conium maculatum	Knotted hedge-parsley	1
Crepis capillaris	Smooth hawk's beard	1
Ajuga reptans	Bugle	1
Barbarea vulgaris	Winter cress	1
Brassica sp		1
Cirsium arvense	Canada thistle	1
Brassica nigra	Black mustard	1
Bromus sp		1
Juncus sp		1
Agropyron repens	Quack-grass	1
Trifolium suaveolens	Shaftel	1
Capsella bursa-pastoris	Shepherd's purse	1
Elymus sp		1
Rosa sp		1
Melilotus alba	Sweet clover	1
Eragrostis abyssinica	Teff	1
Thlaspi arvense	Field penny-cress	1
Lepidium apetalum	Apetalous peppergrass	1
Nepeta cataria	Catmint	1
Iva xanthifolia	Marsh elder	1

TABLE V.—*Kind of weed seeds found in awnless brome grass seed.*

SCIENTIFIC NAME	COMMON NAME	NO. OF SAMPLES IN WHICH FOUND
Bromus secalinus	Cheat	8
Agropyron repens	Quack grass	6
Chenopodium album	Lamb's-quarters	5
Rumex crispus	Curled dock	3
Compositae sp		2
Lappula echinata	European stickseed	2
Verbena urticaefolia	White vervain	1
Digitaria sanguinalis	Large crab-grass	1
Thlaspi arvense	Field pennycress	1
Brassica juncea	Chinese mustard	1
Elymus sp		1
Polygonum aviculare	Knotweed	1
Scirpus sp		1
Setaria viridis	Green foxtail	1

Table VI.—*Showing frequency of occurrence of various weed seeds in the agricultural seeds named at the head of the table.*

SCIENTIFIC NAME	COMMON NAME	*Agrostis alba* Redtop	*Bromus inermis* Awnless brome grass	*Dactylis glomerata* Orchard grass	*Festuca elatior pratensis* Meadow fescue grass	*Linum usitatissimum* Flax	*Lolium perenne* English rye grass	*Medicago sativa* Alfalfa	*Phleum pratense* Timothy	*Poa pratensis* Kentucky blue grass	*Setaria italica* German millet	*Trifolium hybridum* Alsike clover	*Trifolium pratense* Red clover	*Trifolium repens* White clover	Grass mixture	Timothy and alsike clover mixture
Acalypha virginica	Three-seeded mercury	....	....	....	....	....	....	1	....	....	....	....	5	....	....	....
Achillea millefolium	Yarrow	11	....	2	....	....	....	....	....	2	....	....	....	....	2	....
Agropyron repens	Quack grass	....	6	....	1	....	....	4	....	....	....	....	1	....	....	....
Ajuga reptans	Bugle weed	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
Allium vineale	Wild onion	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....
Amaranthus blitoides	Spreading amaranth	....	....	....	....	....	....	7	....	....	....	....	....	....	....	....
Amaranthus sp	Amaranth	1	....	....	....	1	....	60	3	1	....	....	25	....	....	....
Ambrosia artemisiifolia	Rag-weed	....	....	....	....	....	....	14	....	....	1	....	35	....	....	....
Anagallis arvensis	Red pimpernel	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
Anthemis arvensis	Field camomile	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....
Anthemis cotula	May-weed	2	....	....	....	....	....	....	1	2	....	3	2	2	1	1
Anthoxanthum odoratum	Perennial sweet vernal grass	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....
Anthyllis vulneraria	Kidney vetch	....	....	....	....	....	....	1	....	....	....	....	2	....	....	....
Apera spica-venti	Silky bent-grass	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....
Atriplex sp	....	....	....	....	....	....	....	4	....	....	....	....	2	....	....	....
Barbarea vulgaris	Winter cress	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....
Brassica arvensis	Charlock	....	....	....	3	2	....	....	....	....	....	....	8	....	....	....
Brassica juncea	Chinese mustard	....	1	....	1	2	....	11	....	....	....	....	9	....	....	....
Brassica nigra	Black mustard	....	....	....	....	....	....	1	....	....	....	....	1	....	....	....
Brassica sp	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
Bromus racemosus	Smooth chess	....	....	1	7	....	....	....	....	....	....	....	1	....	....	....
Bromus secalinus	Chess	....	8	3	11	....	....	....	....	....	....	....	....	....	....	....
Bromus sp	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
Camelina sativa	Large-seeded false flax	....	....	....	....	....	....	1	....	....	....	....	2	....	....	....

COMMON NAME	*Agrostis alba* Redtop	*Bromus inermis* Awnless brome grass	*Dactylis glomerata* Orchard grass	*Festuca elatior pratensis* Meadow fescue grass	*Linum usitatissimum* Flax	*Lolium perenne* English rye grass	*Medicago sativa* Alfalfa	*Phleum pratense* Timothy	*Poa pratensis* Kentucky blue grass	*Setaria italica* German millet	*Trifolium hybridum* Alsike clover	*Trifolium pratense* Red clover	*Trifolium repens* White clover	Grass mixture	Timothy and alsike clover mixture
epherd's purse	1								6		2	1	1		
dge	7		1	5				7	21			3		2	1
nd-bur							17					2			
							44								
							6								
mmon mouse-ear	2								17		2		1	1	
mb's-quarters		5		6	2		72	3			4	39			1
emont's goosefoot				2			35	1		1		6	1		1
ttle-leaved goosefoot							4								
-eye daisy								1							
ild chicory							32								
nada thistle									1		2	1		1	
ll thistle							1	1				2			
		2					4					1			
ison hemlock							1					1			
eld bindweed							2								
	1														
nooth hawk's beard							1					1			
											1				
eld dodder							12					3			
over dodder							13					2			
rge-seeded alfalfa dodder							5								
nall-seeded alfalfa dodder			1				14								
og's-tail grass						2									

		1														
		6		1					1	1						
								1								
	Wild carrot							15					13			
usa	Small crab-grass							3	2		1	1	50			1
nalis	Large crab-grass	2	1		5			4	2	1			25			1
-galli	Barnyard grass				1			36	1		2	1	34			
		1														
			1		1								1			
nica	Teff							2					1			
		1						17					5			
	Rocquette							35		1						
lata	Milk purslane							1					3			
i	Spurge							2	1				21			1
	Rat's-tail fescue-grass	6					1									
					1											
	Fowl meadow grass									1					1	
	Grasses				1			11	1	2			9			
osa	Gum-plant							9								
us	Wild sunflower					2		9								
	Velvet grass			2			2						1		1	
n	Squirrel-tail grass				1											
ratum	St. John's wort									1						
	Poverty weed							6				1				
	Marsh elder												1			
		10		3	1			1	2	2		1	1	2	2	1
	Mint							10					2			
a	European stickseed		2													
ii occidentalis	Hairy stickseed							4								
nis	Nipple-wort				1		1									
								5								
um	Apetalous peppergrass	3		2	1			2	10			6	3			1
stre	Field cress							3								
	Hoary cress							4								
icum	Peppergrass	2		2	1				1	3				1		
	Round-leaved toad-flax												1			
	Pale-spiked lobelia	2														

COMMON NAME	*Agrostis alba* Redtop	*Bromus inermis* Awnless brome grass	*Dactylis glomerata* Orchard grass	*Festuca elatior pratensis* Meadow fescue grass	*Linum usitatissimum* Flax	*Lolium perenne* English rye grass	*Medicago sativa* Alfalfa	*Phleum pratense* Timothy	*Poa pratensis* Kentucky blue grass	*Setaria italica* German millet	*Trifolium hybridum* Alsike clover	*Trifolium pratense* Red clover	*Trifolium repens* White clover	Grass mixture	Timothy and alsike clover mixture
d's-foot trefoil							7								
mmon mallow							10								
ntless camomile	1														
llow trefoil							16				4	3	2		1
ite sweet clover							51					1			
all-flowered melilot							8								
							7					2			
tmint											2	1			
ening primrose								3				3			
							1								
llow wood-sorrel								1	1		1				
d-witch grass	1		1				39	1		2	1	35			1
reading panicum							13					13			
olly panicum	4		3					2	6			2		1	
itch grass							1								
ld paspalum				1											
nder paspalum												4			
-tongue							3					1			
wkweed picris							1								
acted plantain	3			7			3					9			
ckhorn	2		4	2		1	56	4	2			44			
mmon plantain	1							2	3		3	5	5	1	1
ack-seeded plantain	8						3	15			5	71	4		1
	1														

	May grass						1									
	Wood meadow-grass			1												
re	Knotweed		1					23					3			
ulus	Wild buckwheat				1	2		11								
lvanicum	Pennsylvania smartweed				1											
ria	Lady's thumb				7			5	1		1		47			
um	Arrow-leaved tear-thumb							1								
								25					4			
	Purslane									1						
ensis	Cinquefoil	5							17	2		3	3	4	2	1
	Heal-all							3				1	8			
uosum	Narrow-leaved mountain mint	2													1	
							1			1						
					1								1			
								1								
	Black-eyed susan	4						1	3						1	
	Sheep sorrel	5		2				2	5	13		12	31	5	3	
	Curled dock		3	5	17			15	4	4		3	54			
	Bitter dock				1			1						1		
					1											
lia	Russian thistle					1		75					3			
	Cow cockle					1		4								
		2	1	1	1			1	4	2			6	3	1	
	Yellow foxtail				2	2		47	2		2		66			
	Green foxtail				3	2		151	6		2	5	113	1		1
	Blue field-madder		1				2									
	Spiny sida							2					12			
	Sleepy catch-fly	1							1	1					1	
	Forked catch-fly							5				1	2			
	Night-flowering catch-fly							4	1			6	19	1		
	Buffalo bur							1								
					1			10					22			
	Spiny-leaved sow thistle								2	1			9			
	Rough rush grass							5					8			
								28								
	Common chickweed													1		

NTIFIC NAME	COMMON NAME	*Agrostis alba* Redtop	*Bromus inermis* Awnless brome grass	*Dactylis glomerata* Orchard grass	*Festuca elatior pratensis* Meadow fescue grass	*Linum usitatissimum* Flax	*Lolium perenne* English rye grass	*Medicago sativa* Alfalfa	*Phleum pratense* Timothy	*Poa pratensis* Kentucky blue grass	*Setaria italica* German millet	*Trifolium hybridum* Alsike clover	*Trifolium pratense* Red clover	*Trifolium repens* White clover	Grass mixture	Timothy and alsike clover mixture
sp.					1								3			
rense	Field penny-cress		1					1	1				1			
losa	Knotted hedge-parsley				1			1								
agrarium	Hop clover						1									
arvense	Rabbit-foot clover												1			
filiforme	Yellow suckling clover						1						1			
sp.								2					1			
suaveolens	Shaftel							6					1			
sp.								2								
e sp.					2			2								
ned		2			1			11	3	2		1	4	2		
blattaria	Moth mullein	1														
thapsus	Common mullein	1														
stata	Blue vervain	3						2	1			1	5			
icinalis	European vervain							2	1				6			
icta	Hoary vervain				1			2								
ticaefolia	White vervain	1	1					2					6			
rvensis	Corn speedwell								1	7						

Y. 4616

THE UNIVERSITY OF NEBRASKA

TWENTY-THIRD ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF

NEBRASKA

PRESENTED TO THE GOVERNOR FEBRUARY 1, 1910

THE UNIVERSITY OF NEBRASKA

TWENTY-THIRD ANNUAL REPORT

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PRESENTED TO THE GOVERNOR FEBRUARY 1, 1910

LINCOLN, NEBRASKA
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LETTER OF TRANSMITTAL

THE UNIVERSITY OF NEBRASKA

AGRICULTURAL EXPERIMENT STATION

To His Excellency, Ashton C. Shallenberger, Governor of Nebraska:

SIR—In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Twenty-third Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
February 1, 1910. *Director.*

GOVERNOR'S CERTIFICATE

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT,
LINCOLN, FEBRUARY 1, 1910.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR—I hereby acknowledge receipt of the Twenty-third Annual Report of the Nebraska Agricultural Experiment Station.

ASHTON C. SHALLENBERGER,
Governor.

THE OFFICIAL ROSTER OF THE STATION

THE GOVERNING BOARD.

(THE REGENTS OF THE UNIVERSITY.)

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J. S. DALES, *Financial Secretary.**

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W. W. MARSHALL, *Executive Clerk.*

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G. Herbert Coons, A. B., *Assistant in Agricultural Botany.*
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W. W. Burr, B. Sc., *Assistant in Soils and Crops, North Platte.*
Erwin Hopt, B. Sc., *Assistant in Crops and Horticulture, North Platte.*
S. W. Perin, *Farm Superintendent.*
†Miss Louise M. Allen, A. M., *Scientific Assistant, Seed Testing.*

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TWENTY-THIRD ANNUAL REPORT

EXPERIMENTAL WORK

The work of the Nebraska Agricultural Experiment Station for the current year has been as follows:

The Station is established to conduct investigations for the discovery of scientific principles which bear upon farm practice. Under the law, a portion of the work of the Station must be confined wholly to original investigation of a strictly scientific character which is in some way related to the improvement of agricultural practice. The Adams fund appropriated by the Federal Government is limited to these lines of investigation and cannot be used for popular demonstration purposes or for general administration of Station affairs.

The Federal appropriations known as Hatch appropriations and all State appropriations for experimental work are available for less technical lines of investigation, which may include a study of the adaptation of scientific principles already worked out to the practical needs of the farmer and the demonstration of some of these principles as proof that they can be used to improve general farm practice.

The work of the Experiment Station has grown so much in recent years and the outside demand for information on farm problems has been so great that many lines of investigation have been attempted without sufficient appropriation available to prosecute these investigations vigorously, and no rapid progress can be made in some of these lines without an increase in the State appropriation available for the central Station. The lines of investigation now in progress would be much facilitated and many new lines of work demanded by the people might be undertaken if the State would make a specific appropriation from the general fund to promote the work of the central experimental plant or would appropriate a sufficient amount of money to the University for general agricultural work so that more funds might become available from this source.

The lines of investigation carried on under the Adams fund are definitely outlined for the Office of Experiment Stations in the United States Department of Agriculture and are approved by that office before investigations in these lines can proceed. At the present time these lines of investigation are as follows:

PLANT DISEASES.—Under plant diseases the dry rot of potatoes, scab of potatoes, alfalfa crown disease, the plum canker, and cedar rust are being studied to determine what method of treatment will be successful in exterminating or controlling these diseases.

SOIL INVESTIGATION.—In the investigation of soils the composition and origin of humus and methods of determining humus are being studied, together with the characteristics of the soils of the transition region or the loess area in Nebraska which covers a large proportion of the southeast, central, and southwestern portions of the state. In the composition of soils extensive work has been done to determine the effect of cultivation and cropping upon the loess soils of different sections of Nebraska. In this study it has been found that all the loess soils under consideration are well supplied with potash, phosphoric acid, and lime, the losses of these constituents caused by thirty or forty years' cropping being too small to be detected by chemical analysis. The content of nitrogen, of vegetable matter, and of humus is high in the virgin soils but has fallen very rapidly under cultivation, the greatest losses being found where the surface has been washed or blown away. The destructive action of wind and water, however, does not extend to the mineral constituents and for this reason the restoration of the fertility of farms the soil of which has been impoverished should be an inexpensive matter where clover and alfalfa are used in a rotation to build up the humus and nitrogen in the surface soil. A full report of this investigation may be found in Bulletin 111, recently published.

STRENGTH OF BONE.—The work of investigation to determine the effect of feed on the strength of bone reported in Bulletin 107 fects on the strength of bone in growing pigs of various supplementary feeds. Tankage, sodium phosphate, lime water, bone-meal, as supplementary feeds to corn, are compared with corn alone, all lots receiving 10 per cent of ground alfalfa in order to furnish some variety to the feed. The experiment is not yet completed.

TUBERCULOSIS INVESTIGATION.—The investigation of the prevalence of tuberculosis in hogs and the method of their infection is being studied in cooperation with the Bureau of Animal Industry. Examination of the fecal matter from cows has shown the presence of virulent germs of tuberculosis, which readily becomes a means of infecting hogs following these tuberculous cattle. A preliminary report on this subject was contained in the Twenty-second Annual Report and a further discussion will occur in the appendix of this Report.

SWAMP FEVER.—A disease known as "swamp fever" has been prevalent in the central northern portion of the State for the past three or four years and efforts have been made to determine the cause and treatment for the disease. We have found that it is possible to transmit this disease from a diseased to a healthy horse by blood inoculation in the infected districts. A solution of this problem would be worth many thousand dollars to the infected areas, and it is believed that some solution can be reached and a remedy applied by a continuation of the investigation.

CEREAL CROPS.—A study of the water requirements of growing corn has been carried on for several years to determine the relation between leaf area and water requirements, with an idea of securing a type of corn giving the largest yield per acre for a given use of water. When once this question has been thoroly worked out, it will be of great importance to those sections of the country which are likely to be visited by periodic drouths before the maturing of the crop.

Investigation of the effect of competition in cereal crops has also been carried on for a number of years with corn, and the evidence seems to indicate that where corn is grown at the rate of three or more stalks per hill the good ears which develop under this competition produce larger yields per acre in subsequent years than even better ears may produce when selected from fields where only one or two stalks per hill have been used and where there was little or no competition in the production of perfect ears.

The effect of inbreeding and crossbreeding corn is also being studied to determine how much inbreeding is necessary to fix the type of corn and to what extent crossing is permissible in securing a maximum yield of corn.

WINTERKILLING INVESTIGATION.—Investigations are in progress to determine the effect of different moisture content in the soil and of different degrees of cold upon winterkilling of raspberries, apples and peaches. These temperatures are produced largely by artificial means.

HEREDITY INVESTIGATIONS.—In heredity studies considerable work has been done to determine (1) whether Mendel's principles of heredity apply to the inheritance of fluctuating variations as well as to discontinuous variations and (2) whether it is possible to "fix" true "intermediates" in case of hybrids, and, if so, how this may be done. Crosses have been made between many of the races of the following plants: beans, corn, petunias, gourds, nasturtiums, sweet peas, snap dragons, phlox, verbena, balsam, and geraniums. A discussion of the inheritance of color in seeds occurs in the Twenty-second Annual Report. If the law governing variation in plants can be worked out, it will be of great importance in determining the methods which will be used in the improvement of varieties for economic purposes.

Lines of investigation pursued under the Hatch or State appropriations are as follows:

HOG CHOLERA.—The immunization of hogs against cholera has became a matter of great economic importance to the farmer. The work of the Bureau of Animal Industry of the United States Department of Agriculture and the work of this Station have proven, after many years of labor, that a blood serum may be produced from hyperimmunized hogs which, when injected into healthy hogs, will protect them against cholera for a limited time and has a considerable degree of protection to hogs which have been infected with cholera but have not yet sickened with the disease. Our Experiment Station recommends the use of this serum in all herds which have been infected with cholera and in all herds which may possibly be subject to infection with cholera on account of its presence on adjoining farms. By the systematic use of this serum it is thought that cholera can be entirely stamped out.

The last Legislature appropriated $5,000 to be used by the Experiment Station for the production of hog cholera serum to be available to the farmers of the State thru the deputies of the State Veterinarian who are located in different sections of the State. A report on the means by which this serum can be secured is found in Press Bulletin 31, recently issued.

The production of this serum has proved to be so expensive and so slow a process that the $5,000 above mentioned is entirely inadequate to produce the serum called for by the hog raisers of the State, and it is apparent that an extensive plant with a laboratory, adequate housing, and sufficient land to carry 200 or 300 hogs must be available if this Station is to furnish the serum which will be demanded in stamping out the outbreaks of hog cholera in the State. Such an investment of State funds would probably save a million dollars annually to the State when once the system was thoroly enough established to furnish an unlimited amount of serum and sufficient service of veterinarians to vaccinate all the hogs in a locality whenever an outbreak occurred. Since it is possible to produce this serum and keep it for some time in storage, it would seem as tho a plant might be established which would absolutely control the hog cholera situation in the State if sufficient money was available and the farmers would be prompt in notifying the State Veterinarian of cholera outbreaks.

CATTLE FEEDING.—The Station is continuing its investigation to determine the most economical proportion between corn and alfalfa for fattening cattle, using heavy, medium, and light rations of corn for this purpose. A bulletin upon this subject will soon be issued.

The feeding experiments conducted for a number of years have proved the efficiency of alfalfa hay as roughage when fed with corn, and also that corn-stover is a very profitable feed to use as half the roughness in connection with alfalfa hay. The utilization of corn-stover in this way where cattle feeding is practiced will add about 25 per cent to the value of the corn crop in comparison with utilizing only the grain produced. The very high price of hay at this time is due to the fact that little attention is given to preserving the roughage grown in our cornfields, and the evidence is conclusive that upon our high-priced land we must utilize the fodder by harvesting and feeding the corn either without husking or by the use of improved husking machinery which makes the stover available in the best possible form.

The Experiment Station for several years has used a silo in feeding both beef and dairy cattle, altho it has reported no technical experiments. The evidence all points to the fact that in no way can the corn crop be made to produce as much feed per acre as thru the silo where a herd is kept large enough to consume the silage from a medium-sized silo of 14 or 16 feet in diameter by 30 feet in height. Where a herd of dairy cattle is kept, the profits will be even greater than with beef cattle. The introduction of the silo will practically double the number of cattle which may be kept upon any farm if silage is used for both summer and winter feeding.

WINTER WHEAT INVESTIGATION.—For many years this Station has endeavored to extend the area of winter wheat production and increase the yield per acre by the selection of suitable varieties and by the improvement of methods.

The improvement of Turkey Red wheat by the selection of individual plants which show desirable characters and high yielding power has been carried on for the past seven years. The most desirable plants have been retained and increased from year to year until a number of such selected strains are now available in considerable quantities and within a year or two will be ready for distribution among farmers who can give them special care and attention.

An effort has been made, thru crossbreeding other varieties with the Turkey Red wheat, to secure a smooth-headed variety with a hard berry. Two or three promising strains of this character are being developed, but their yielding power has not yet been tested.

Variety tests of oats have shown that the early varieties are superior to the later varieties in yield and in escaping possibility of drouth during the ripening period. Selection is being carried on with Kherson oats to improve the character of the grain. Bulletin 113, in press, gives a report of the experimental work on this subject.

POTATO INVESTIGATIONS.—Investigations have been carried on to determine the best varieties of potatoes, and the relative value of seed from different regions. Up to the present time, local-grown potatoes which were grown under a straw mulch have given the best results where all seed was kept under the same conditions thru the winter in order that one variety might not be favored by better winter conditions than those afforded to other varieties in the test. Under this condition the results were as follows: Local seed grown under a mulch from two to four years gave the largest yield, followed by North Dakota and Minnesota seed, and then by South Dakota, home-grown cultivated, Hemingford, Nebr., Greeley, Colo., and Callahan, Colo., in the order named.

ORCHARD MANAGEMENT DEMONSTRATIONS.—Spraying demonstrations carried on for the last three years have shown that profitable crops can be grown where proper care is given to the trees and careful spraying methods are followed, and that without such methods there is little or no profit in growing orchard fruits.

INSECT PESTS.—The life history of a number of insect pests has been studied in detail within the past year and methods for preventing their depredations have been offered where possible. This investigation has included work upon the seed wheat Eleodes, the parasites of the White-marked Tussock Moth, the melon aphis, the squash borer, cucumber beetle, and squash bug, the Pine-tip Moth, the Corn-ear Worm, Potato Stalk borer and Strawberry Leaf-roller.

COOPERATIVE EXPERIMENTS

Cooperative demonstrations in spraying apple orchards are carried on with a number of farmers in the State to prove the advantage of spraying commercial orchards as a business proposition. Each demonstration, where carefully carried out, in the past has furnished convincing proof on this point.

About 40 farmers are cooperating with the Station in testing a large number of local varieties of corn to determine what varieties are best adapted to the several localities. A few farmers are testing winter barley, which has not proved hardy except in the southeastern portion of the State. A line of cooperative experiments will be carried on with farmers in certain sections of the State to determine the advisability of using sweet clover as a green manure crop and as a crop for preparing the ground for alfalfa.

A number of farmers will cooperate with the Station to test the value of commercial fertilizers on various soils in different sections of the State.

The Station is cooperating with the Bureau of Plant Industry of the United States Department of Agriculture in the breeding and selection of improved varieties of winter wheat and in testing the milling and baking qualities of the same, in an effort to secure an improved strain of Turkey Red wheat of superior yielding and milling qualities.

A Seed Laboratory is maintained in cooperation with the Bureau of Plant Industry, U. S. Department of Agriculture, to determine the kind of adulterants and impurities and the percentage of germination of seed sold upon the market.

At the North Platte Station we are cooperating with the Bureau of Plant Industry, United States Department of Agriculture, to test different rotations and methods of tillage, to study alkali resistant crops, and in growing forest trees.

THE NORTH PLATTE SUBSTATION

Investigation at the North Platte Station is carried on to determine the best varieties of winter and spring grains, the best forage crops, the best methods of tillage, and rotations for crop production.

We have demonstrated that winter wheat can be grown with profit on the hard table-lands in this region by a period of summer fallow preceding the time of sowing grain. The yields per acre for the past four years on summer tilled land have been as follows: 1906, 42 bushels per acre; 1907, 59 bushels per acre; 1908, 50 to rainfall. Experiments to determine the time of seeding have indicated in general that winter wheat sown about the middle of September gave higher yields than that sown at later dates, altho the late seeding of 1908 harvested in 1909 gave a little higher yield than the earlier sown grain. This was probably due to the fact that a 3-inch rain occurred very shortly after the late sown wheat was planted in that year. The two leading varieties of winter wheat have been the Kharkov, introduced thru the United States Department of Agriculture, and the Turkey Red, a standard variety long in use in this State.

SPRING WHEAT.—Several years' test with spring wheat has shown the durum wheats to be very much superior to the local varieties in common use in this region, and durum wheat is now largely used for spring sowing. The different varieties of durum wheat in 1908 produced from 26.5 to 33.6 bushels per acre, where the average for the three previous years had been about 28 bushels per acre. Some farmers discriminate against growing durum wheat because it does not sell at as high a price on the market as winter and local spring wheats. The Station has proven by experiments that durum wheats are worth at least as much as corn, pound for pound, in feeding hogs, and that, at current prices of corn, durum wheat can profitably be fed to hogs in the production of pork.

BARLEY.—The yields of barley for the year 1909 were small, producing on an average about 20 bushels per acre. This low yield was partly due to the blowing of the soil and injuring the grain after sowing, which caused a very poor stand. Common barley produced 21.4 bushels per acre, which was a larger yield than that given by any of the other varieties.

OATS.—Of the twelve varieties sown, the Kherson oat produced 42 bushels per acre, the Burt oat 38 bushels, the Texas Red 38 bushels, the Black American 37 bushels, the Sixty Day oat 36 bushels, and other varieties made lower yields. In every instance the early varieties were superior to the late varieties.

FORAGE.—Among the annual forage crops, sorghum, or cane, has given the most satisfactory results at this Station for hay. We have never failed to secure large yields per acre of forage upon land which was under thoro cultivation, and have been very successful in raising sorghum for hay by breaking sod land in May and sowing to cane with a press drill after thoroly working the sod with a disk harrow. Upon other land we have sometimes produced eight tons of forage per acre, tho five or six tons is an average crop.

Alfalfa has produced about four to five tons of hay per acre on the bench land where it has not been pastured, and upon land which has been pastured with eight or ten hogs per acre as much as three tons per acre of alfalfa hay has been produced. Alfalfa can be grown in all of the valleys in Western Nebraska and will probably prove the most profitable crop which can be grown upon these lands. Upon the high table-lands it will produce from one to two tons of hay per acre in the region of the North Platte Station after it is thoroly established, depending much on the timely rainfall, but even one ton per acre where hay is worth from $6 to $8 per ton makes a valuable crop and in any normal year a ton and a half to two tons per acre may be grown. Abundant alfalfa may be grown on the table for pasturing hogs, provided the land is not overpastured. The value of alfalfa in wintering cattle, horses, and hogs has been shown to be superior to prairie hay or to sorghum hay. It has, however, been shown that where a sufficient amount of alfalfa is not available to use exclusively for roughness it should be fed with about an equal amount of either prairie hay, cane, or wheat straw, or any of the common rough feeds available in the country, both feeds being available all the time so that the animal may choose between them. Animals thus fed will do almost as well as upon alfalfa hay exclusively and can be wintered more cheaply in this way.

LIVE STOCK EXPERIMENTS

CATTLE.—Experiments are in progress to determine the relative tions, namely: alfalfa and prairie hay, alfalfa and cane, prairie hay and cane. These steers are being kept for the third winter upon the same rations. During the summer they all run together upon a good native canyon pasture consisting largely of buffalo, grama, and wheat grasses. It is proposed to determine the cumulative effect of three winters' feeding upon the different rations and to put these cattle upon the market in the fall of 1910 as three-year-old steers. On November 1, 1909, these lots averaged as follows:

Lot 1, fed alfalfa in winter	1022 pounds
Lot 2, fed prairie hay in winter	930 pounds
Lot 3, fed cane in winter	985 pounds
Lot 4, fed alfalfa and prairie hay in winter	1057 pounds
Lot 5, fed alfalfa and cane in winter	1009 pounds
Lot 6, fed prairie hay and cane in winter	973 pounds

In this experiment it has been found that the steers going upon grass in the thinnest condition in the spring make the largest summer gains, but these are not sufficient to overcome the losses in winter, so that all lots receiving alfalfa hay in winter were heavier at the time they went into the feed lots in November, 1909, than the lots which had received no alfalfa hay.

HORSES.—A similar experiment, to test the efficiency of different kinds of rations for wintering horses, has been carried on. Thirty weanling colts and mules were selected in 1907 and divided into three lots as evenly as possible with eight colts and two mules in each lot. When these colts came from the pastures November 1, 1909, as two-year-old colts, they weighed as follows:

Lot 1, alfalfa hay in winter and alfalfa pasture, 1162 pounds average.

Lot 2, alfalfa hay in winter and native pasture, 1063 pounds average.

Lot 3, native hay in winter, native pasture, 1026 pounds average.

During the two years these colts have been on experiment,

Lot 1 has gained 574 pounds average.
Lot 2 has gained 476 pounds average.
Lot 3 has gained 409 pounds average.

All colts were fed four pounds of grain per day during the first winter, and Lot 3, upon prairie pasture and prairie hay, was fed some grain in winter as yearlings. These colts will be kept until they are four years old to determine whether or not those receiving alfalfa are heavier than those not receiving alfalfa when in the same condition of flesh.

HOGS.—Extensive experiments have been carried on to determine the methods of feeding hogs which will prove most profitable for the farmer in western Nebraska. One chief line of investigation during the present season is to determine the most profitable method of feeding alfalfa to hogs during the fattening period. Alfalfa meal is being fed in comparison with alfalfa hay, both cut and fed in racks without cutting. Different proportions of corn and alfalfa are being used to determine what is the most profitable ratio between the corn and alfalfa. In both cut and ground alfalfa we are feeding 10 per cent alfalfa and 90 per cent corn, 25 per cent alfalfa and 75 per cent corn, 50 per cent alfalfa and 50 per cent corn, during the winter season. It is probable that in fattening hogs somewhere between 10 and 25 per cent of chopped or ground alfalfa fed with corn will be more profitable than a larger proportion; while in feeding brood sows, as much as 50 per cent alfalfa can be used to advantage and possibly even a larger amount where the alfalfa is of extremely high quality.

In pasturing alfalfa in summer, brood sows upon weaning their litters have been found to make gains of about one-half pound per day with no grain, while it has been found more profitable to feed young pigs after weaning time a medium grain ration thruout the summer season rather than ask them to live upon alfalfa pasture alone, since the young pig finds it impossible to eat and to digest enough alfalfa to make reasonable growth. A bulletin covering three years' work on this subject will soon be ready for distribuplanting 200 apple, cherry, and plum trees on the table-land, which is 225 or 250 feet above water, with an elevation of 3,000 feet. Several kinds of shrubs and ornamental trees have been planted to determine what shrubs can be grown successfully by the farmer to beautify his home. Some of the hardy perennial flowering plants are also being tested. Peonies, phlox, and roses promise to give very satisfactory results, while spireas and syringas, tartarean and orange honeysuckles, lilac and snowballs and a much more extended list seem to be reasonably hardy. It is proposed to extend this work considerably in the future.

FORESTRY.—The area being planted to forest trees in cooperation with the United States Forest Service consists of ten acres of bench land and about fifteen acres of high table-land and canyon land. The canyon land will be largely increased in the future. The planting of conifers on the sides of canyons with north, east, and southeast slopes has been very successful up to the present time, and the outlook is very encouraging. It is necessary only to plant these conifers and to protect them against live stock and fire. The success in planting conifers upon level cultivated land has not thus far been satisfactory but we hope for better results in the future.

The deciduous trees which have been planted have been very successful. Cottonwoods are being grown upon the bench land. Some of these trees three years from planting are 12 and 15 feet high. Black locust and honey locust are extremely vigorous and hardy, and catalpas, elm, green ash, golden willow, and many other sorts are growing successfully. On the high table-land the planting has been limited to black and honey locust, catalpa, green ash, white elm, with a few other varieties. A detailed report upon this planting will be made thru bulletins at a later date.

STATION STAFF

Within the past year the following changes in the Station staff have taken place:

By the resignation of Dr. A. T. Peters the Station has lost one of its oldest and most efficient workers, Dr. Peters having been engaged in Station work in Nebraska for the past sixteen years.

Dr. J. H. Gain, for some years associated with Dr. Peters in

Animal Pathology, has been placed in charge of the Department as Animal Pathologist.

Mr. Alvin Keyser, of the Department of Soils, resigned in April, 1909, and his Department was reorganized and Mr. C. W. Pugsley was transferred from the Department of Animal Husbandry and placed in charge of the Department of Agronomy and Farm Management, carrying the investigation in farm management, crop rotations, and commercial fertilizers.

The Department of Field Crops was reorganized as a Department of Experimental Agronomy, remaining in charge of Mr. E. G. Montgomery.

Mr. E. M. Little resigned as Assistant in Dairy Husbandry March 1, 1909.

Mr. T. A. Kiesselbach was appointed Assistant in Agronomy (Crops).

Mr. Erwin Hopt was appointed Assistant in Crops and Horticulture, Substation, North Platte, June, 1909.

Mr. G. Herbert Coons was appointed Assistant in Agricultural Botany November, 1909.

IMPROVEMENTS

Since the last Report, a standpipe has been erected at the University Farm and a complete pumping plant installed, at a cost of $6,000.

A greenhouse and potting sheds have also been erected for the use of the Landscape Gardener, at a cost of $3,000.

Four acres of land has been added to the University farm for general administrative purposes, at a cost of $3,750.

None of these improvements deal directly with experimental work.

FARMERS' INSTITUTES

Several members of the Experiment Station staff have assisted in Farmers' Institutes during the year. One hundred and fifty Institutes were held during the season of 1908-1909, and 154 Institutes, 38 Boys' and Girls' Contests, and 6 Farmers' Institute Schools are scheduled for the year 1909-1910.

The demand for both Farmers' Institutes and Farmers' Institute Schools exceeds the ability of the University to furnish such Institutes by at least 25 per cent for the regular Institutes and 100 per cent for the Farmers' Institute Schools. Since it costs at least five times as much to hold a Farmers' Institute School as to hold a regular Farmers' Institute, it does not seem good policy on the part of the University to increase the Institute Schools beyond the number now held until sufficient money is available so that this can be done without cutting down the regular one- and two-day Institutes. It is to be hoped that the funds available for this work will be increased.

ORGANIZED AGRICULTURE

The various agricultural societies meet at the University each year, under the name of "Organized Agriculture," the following societies participating: Association of Agricultural Students, the State Board of Agriculture, the State Horticultural Society, the Nebraska Dairymen's Association, the State Corn Improvers' Association, the State Home Economics Association, the Improved Live Stock Breeders' Association (which this year for the first time included a Special Horse Session), with sessions for the Aberdeen-Angus Breeders', the State Swine Breeders', the Red Polled Breeders', the Sheep Breeders', and the Shorthorn Breeders' Associations. The Farmers' Institute Conference for delegates from the various local societies met with Organized Agriculture. A Good Roads Meeting was held in the City in connection with Organized Agriculture.

PUBLICATIONS

Bulletins giving the results of investigation in the Experiment Station are published in editions of 20,000 to 25,000 each, except where limited editions are published upon some technical subject. These bulletins are distributed free of charge to any resident of the State making application. There is at the present time a regular mailing list within the State of 15,000 names. These are continually being added to, and it is desired that all farmers who are interested in the publications of the Station should ask to be placed on the regular mailing list.

The publications of the Station since those named in the last Annual Report are as follows:

Twenty-second Annual Report. Presented to the Governor February 1, 1909. 5,000 copies.

Bulletin No. 110 (Vol. XXI, Art. IV). Report of the Nebraska Seed Laboratory. By E. Mead Wilcox and Miss Nelle Stevenson. Distributed June 25, 1909. 22,000 copies.

Bulletin No. 111 (Vol. XXII, Art. I). Changes in the Composition of the Loess Soils of Nebraska Caused by Cultivation. By F. J. Alway. Distributed December 15, 1909. 25,000 copies.

Bulletin No. 112 (Vol. XXII, Art. II). Experiments with Corn. By E. G. Montgomery. Distributed December 15, 1909. 25,000 copies.

Bulletin No. 113 (Vol. XXII, Art. III). Oats. By E. G. Montgomery. (In press.) 25,000 copies.

Press Bulletin No. 30. Rolling Winter Wheat. By E. G. Montgomery. Distributed April 3, 1909. 25,000 copies.

Press Bulletin No. 31. Production of Hog Cholera Serum. By J. H. Gain. Distributed December 15, 1909. 21,000 copies.

NEW EXPERIMENTAL SUBSTATIONS

The Legislature of 1909 passed two bills for the establishment of new experimental substations, as follows:

House Roll No. 114

(Introduced by Mr. Carr.)

AN ACT to establish an experimental station north of the sixth standard parallel and west of the second guide meridian in the State of Nebraska, including the counties of Sioux, Dawes, Box standard parallel and west of the second guide meridian in the State of Nebraska, including the counties of Sioux, Dawes, Box Butte, Sheridan, Cherry, Keya Paha, Brown and Rock, which station shall be under the control and management of the board of regents of the state university.

Section 2. The board of regents are hereby authorized and empowered to select the necessary lands, not less than one section and purchase the same and to make all necessary improvements in the way of buildings, fences, etc., and to take such steps as they deem necessary to successfully establish such station.

Section 3. The board of regents shall have control and supervision of said station and shall appoint skillful superintendents and such other employees as to them may appear necessary, to obtain the best results. They shall fix the salaries and compensation of employees and establish such rules and regulations as they may from time to time deem best.

Section 4. The object of this experiment station shall be to determine the adaptability of the arid and semi-arid portions of Nebraska to agriculture, horticulture, forest tree and live stock growing, such as the producing of grain, grasses, root crops and fruits of kinds commonly grown in same latitude in other states, also the most economical methods of producing such crops without irrigation.

Section 5. The proceeds arising from the sale of products of said station shall be applied to the liquidation of the running expenses, and all money so accruing shall be credited as coming from the state and be applied as part or whole payment of any amount which may be appropriated from the funds of the state for the maintenance of said station.

Section 6. To enable the board of regents to carry out the provisions of this act they are hereby authorized to expend such

000.00) be and is hereby appropriated out of the moneys in the temporary university fund for the purpose of carrying out the provisions of this Act.

Approved March 20th, 1909.

House Roll No. 18

(Introduced by Mr. Bushee.)

AN ACT to establish an experimental station west of the one hundred and second meridian, in the State of Nebraska, fixing the control and management of the same and making an appropriation therefor.

Be it Enacted by the Legislature of the State of Nebraska:

Section 1. That for the furtherance and promotion of agricultural, horticultural, and forestry interests of this state, an experimental sub-station shall be established west of the one hundred and second meridian in Nebraska, which station shall be under the control and management of the board of regents of the state university.

Section 2. The board of regents are hereby authorized and empowered to take such steps in conjunction with the authorities of the United States as they deem necessary to successfully establish such station.

Section 3. The board of regents shall have control and supervision of said station and shall appoint skillful superintendents and such other employees as to them may appear necessary, to obtain the best results. They shall fix the salaries and compensation of employees and establish such rules and regulations as they may from time to time deem best.

Section 4. The object of this experiment station shall be to determine the adaptability of the arid and semi-arid portions of Nebraska to agriculture, horticulture and forestry such as the producing of grain, grasses, root crops and fruits of kinds commonly grown in same latitude in other states, also the most economical methods of producing such crops with and without irrigation.

Section 5. The proceeds arising from the sale of products of said station shall be applied to the liquidation of the running expenses, and all money so accruing shall be credited as coming from the state and be applied as a part or whole payment of any amount which may be appropriated from the funds of the state for the maintenance of said station.

Section 6. To enable the board of regents to carry out the provisions of this act they are hereby authorized to expend such amounts as they may deem necessary from any moneys hereafter appropriated to carry out the spirit and intent of this bill, either by the state or the United States as the case might be.

Section 7. That the sum of five thousand dollars ($5,000.00) be and is hereby appropriated out of the moneys in the temporary university fund for the purpose of carrying out the provisions of this act.

Approved April 3rd, 1909.

Pursuant to the instructions of the Legislature, a committee of the Regents on June 15, 1909, started to investigate the sites which had been offered for the proposed substations, visiting the lands in Scotts Bluff County which were made available by the Interior Department for experimental work carried on by the United States Department of Agriculture, a committee of this Department having been appointed to select a suitable site for their experimental work. After due investigation a site was recommended by the committee of the United States Department of Agriculture which was to be in charge of this experiment station for the Government, the site selected being the southeast quarter of section 21, township 23 north, range 55 west, located five miles east of the town of Mitchell and seven and one-half miles northwest of the town of Scottsbluff, in Scotts Bluff County, Nebraska. This site was agreed to as acceptable to the Regents of the University.

Investigation of the sites offered for the station in the northwest section of the State were made with an effort to secure land in the Sand Hills region where the agricultural and forestry possibilities of sand hill land could be determined along with the management of other agricultural lands. After some investigation the Regents indicated that the region of Valentine would be an acceptable region for this Station but did not select any definite site for this purpose.

At this juncture, when the Regents were about to begin the expenditure of money for the establishment of these stations, a doubt arising as to the availability of funds under the forms of legislative appropriations, a friendly mandamus suit was filed in the Supreme Court of Nebraska to determine the legality of the use of moneys from the temporary university fund for the establishment of these stations. The decision of the court, rendered in December, 1909, confirmed the authority of the Regents to proceed in the establishment of these stations in accordance with the act of the Legislature.*

In December, 1909, the agent of the United States Department of Agriculture with whom a cooperative agreement for the operation of the experiment station in Scotts Bluff County was in progress informed the Director of the Nebraska Experiment Station that a ruling had been made by the Secretary of the Interior to the effect that the money which had been promised by the Interior Department for the erection of permanent buildings upon the site above mentioned could not be legally expended for this purpose without additional authority from Congress. The experimental work to be conducted in Nebraska by the United States Department of Agriculture is but one of a number of experimental or demonstration farms which it is proposed to establish upon land under the Reclamation projects which are subject to homestead entry in the Department of the Interior. The purpose of these experimental farms is to give information to the settlers on these lands which will assist them in determining practical farm problems and aid them to pay their annual assessments for water rights and build up prosperous farm communities.

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*Note.—On January 17, 1910, Senator Norris Brown introduced in the United States Senate a bill granting to the University of Nebraska certain lands embraced in the Fort Niobrara Reservation, for the purpose of aiding in the establishment and maintenance of this station. This bill grants a perpetual lease to the University on "all of section thirty-two, six hundred and forty acres; west half and west half southeast quarter section thirty-three, four hundred acres; lot one (thirty-seven and thirty one-hundredths acres) and lot two (sixteen and twenty one-hundredths acres), or section thirty-three, fifty-three and fifty one-hundredths acres; in all, one thousand and ninety-three and fifty one-hundredths acres; all of township thirty-four, range twenty-seven west of the sixth prime meridian." This land is located about one half mile east of the town of Valentine. It is expected that this bill will pass Congress, and preparations are being made to occupy this land for experimental purposes.

Mr. James Cowan has been appointed Superintendent of the Valentine Substation.

The understanding between the Regents of the University and the United States Department of Agriculture was that the Interior Department would furnish the land for this experiment station site and would construct the necessary buildings to permit the carrying on of this experimental work, out of appropriations made by Congress to the Reclamation Service. The recent ruling of the Secretary of the Interior calling for specific authority to use money for the construction of these buildings will delay the experimental work upon this station until Congress shall authorize this expenditure. The Bureau of Plant Industry of the United States Department of Agriculture rules that it has no authority to expend any moneys now available for permanent improvements upon this land, and the Regents of the University hold that they have no authority to expend money for permanent improvements upon land to which they do not hold title, since the discontinuance of the cooperative agreement would cancel their rights to the property in question and would tranfer this property, without recourse, to the Interior Department of the Federal Government.

Unless the difficulties above mentioned are overcome so that experimental work can progress during the season of 1910, it would seem that the State, if it desires to carry on experimental or demonstration work of a permanent character in the extreme western portion of Nebraska, could better afford to own and operate its experimental plant as a State proposition, allowing the Regents at their discretion to cooperate with the United States Department of Agriculture at these stations as they are now doing at other stations. This would enable the Regents to shape the policy of the station in conformity to their views of the needs of the locality.*

ACKNOWLEDGMENTS

The agricultural press, especially those papers located within the State, have shown their appreciation of the work of the Experiment Station by giving liberal space to the experimental work reported and in every way facilitating the extension of useful agricultural knowledge.

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*Note. On March 7, 1910, Secretary R. A. Ballinger approved

THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA

FINANCIAL STATEMENT

RECEIPTS

Received by the state treasurer of Nebraska from the treasurer of the United States, installments for the year ended June 30, 1909, under the act of Congress approved March 2, 1887 (Hatch Fund)	15,000 00	

DISBURSEMENTS

Salaries		10,113 68
Labor		198 51
Publications		2,116 17
Postage and stationery		761 51
Freight and express		142 63
Chemical supplies		124 23
Seeds, plants and sundry supplies		290 96
Feeding stuffs		742 81
Tools, implements and machinery		154 75
Furniture and fixtures		181 25
Scientific apparatus		71 45
Traveling expenses		83 50
Contingent expenses		15 00
Building and land		3 55
	$15,000 00	15,000 00

FINANCIAL STATEMENT—Continued

Received by the state treasurer of Nebraska from the treasurer of the United States, installments for the year ended June 30, 1909, under the act of Congress approved March 16, 1906 (Adams Fund)	11,000 00	
DISBURSEMENTS		
Salaries		8,446 23
Labor		24 10
Postage and stationery		12 15
Freight and express		58 03
Chemical supplies		626 45
Seeds, plants and sundry supplies		471 58
Feeding stuffs		56 50
Library		2 26
Tools, implements and machinery		120 80
Furniture and fixtures		23 10
Scientific apparatus		1,096 29
Traveling expenses		62 51
	$11,000 00	11,000 00

FINANCIAL STATEMENT—Continued

SUPPLEMENTARY

Moneys received by the state treasurer of Nebraska from sources other than the United States for the use and benefit of the experiment station and covered into the "University Cash Fund."

RECEIPTS		
Balance on hand July 31, 1908	6,858 58	
Receipts for the year ended July 31, 1909, from sales of farm products, live stock and sundry other sources	23,831 54	
DISBURSEMENTS		
Salaries		5,390 02
Labor		3,534 61
Publications		8 70
Postage and stationery		605 39
Freight and express		1,003 09
Heat, light, water and power		133 76
Chemical supplies		168 19
Seeds, plants and sundry supplies		3,476 09
Feeding stuffs		8,932 21
Tools, implements and machinery		1,726 93
Furniture and fixtures		97 75
Scientific apparatus		552 93
Live stock		978 32
Traveling expenses		583 33
Building and land		1,153 05
Balance, July 31, 1909		2,345 75
	$30,690 12	30,690 12

FINANCIAL STATEMENT—Continued

APPROPRIATIONS BY THE STATE

SUBSTATION AT NORTH PLATTE

Legislative appropriation of 1909 from the state general fund for support of the substation at North Platte, for the two years ending March 31, 1911	25,000 00	
Expended, year ended November 30, 1909, for feed, labor, live stock, permanent improvements, machinery, services, supplies, superintendence, tools and general maintenance..		11,655 03
Appropriation balance, November 30, 1909....		13,344 97
	$25,000 00	25,000 00

FARMERS' INSTITUTES

Balance, November 30, 1908, of legislative appropriation of 1907, from the state general fund for support of farmers' institutes......	6,754 62	
Legislative appropriation of 1909, from the state general fund for support of farmers' institutes, for the two years ending March 31, 1911	20,000 00	
Expended, year ended November 30, 1909, for clerical services, labor, lecturers' services and traveling expenses, printing, supplies, superintendence, and other necessary expenses		9,367 75
Appropriation balance, November 30, 1909....		17,386 87
	$26,754 62	26,754 62

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THE IMPORTANCE OF THE INOCULATION OF ALFALFA ON NEBRASKA UPLAND SOILS

BY F. J. ALWAY

It is commonly believed that in Nebraska it is unnecessary to inoculate newly sown fields of alfalfa. The rapid increase in the area devoted to this crop, it now having reached 615,329 acres for the whole State, and the ease with which men who have already had experience with alfalfa secure a satisfactory stand, are certainly strong evidence in support of this view. The author, however, is convinced, from observations made in various parts of the State during the past eight years, that the popular opinion is ill-founded and that every man in the State who sows a field of alfalfa should give attention to the matter of its inoculation before the plants are past recovery in case artificial inoculation should be needed. In some cases a half-hour's examination may suffice for a large field, while in others a day or two's labor may be necessary to make sure of the inoculation.

RESULTS OF INVESTIGATIONS ELSEWHERE.

Since Hellriegel and Wilfarth in 1886 proved that the ability of legumes to make use of atmospheric nitrogen is dependent upon the presence of certain bacteria on the roots, many investigations have been conducted to determine the necessity of the artificial inoculation of alfalfa. In the United States, bulletins in which this has been dealt with have been published by the United States Department of Agriculture[1] and by various Experiment Stations. Inoculation of alfalfa by means of soil from fields in which the crop has been thriving was used by Dugger[2] in Alabama in 1897, by Otis[3] in Kansas in 1898, and by Hopkins[4] in Illinois in 1902. Hopkins showed that soil in which inoculated plants of sweet clover (*Melilotus alba*) were growing did as well as that in which alfalfa itself had grown.

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[1] Farmers' Bulletin No. 339.
[2] Bulletin 87, Alabama Experiment Station.
[3] Bulletin 96, Kansas Experiment Station.
[4] Bulletins 76 and 94, Illinois Experiment Station.

The New York Experiment Station[1] has conducted what is probably the most comprehensive field investigation of the need of inoculation for alfalfa. This investigation included cooperative experiments on one hundred fields in different parts of the State. It was found that the desired bacteria were present, at least in small numbers, in practically all the fields, but that in only about one-third of these were the bacteria present in sufficient numbers to produce inoculation of any considerable number of young alfalfa plants.

THE RECOGNITION OF INOCULATED PLANTS.

When the alfalfa seed has been sown in the spring, it is usually possible by the middle of the summer to recognize the uninoculated plants by their more yellow color, smaller size, and general lack of vigor as compared with the inoculated plants. If the field is in a high state of fertility from previous manuring, none of the plants during the first season may show the characteristics of uninoculated plants—really the signs of a deficient supply of nitrogen. Virgin soils, also, when plowed and put in fine tilth may show the same lack of difference. A good illustration of the latter is the field of J. S. Campbell described below. Even in the case of very fertile fields the difference will ordinarily be seen in the second season. The smaller the supply of readily available nitrogen in the soil the more quickly will the want of inoculation become apparent.

The only reliable method of deciding whether a plant is inoculated or not is to examine its roots for the presence of nodules.

The nodules, or tubercules, occur either singly or in clusters attached to the fine roots. They are about as large as alfalfa seeds, or a little larger, and somewhat of the same shape. Frequently they are pear-shaped. The color of the young nodules is white, sometimes with a pink tint. They are most abundant during the growing season. An examination of the roots during the winter may show but few nodules present, and these dark and shrunken. On account of the readiness with which the nodules become detached, it is usually necessary to remove the plant together with much adherent soil by means of a spade and then pick or wash away the soil. If a pail of water be carried to the field and all the roots and adherent soil soaked and then washed in this, the rootlets with the nodules can usually be secured without difficulty. When a red clover plant is pulled up bodily, numerous nodules remain attached to the roots, but when an alfalfa plant is similarly treated the nodules remain in the ground.

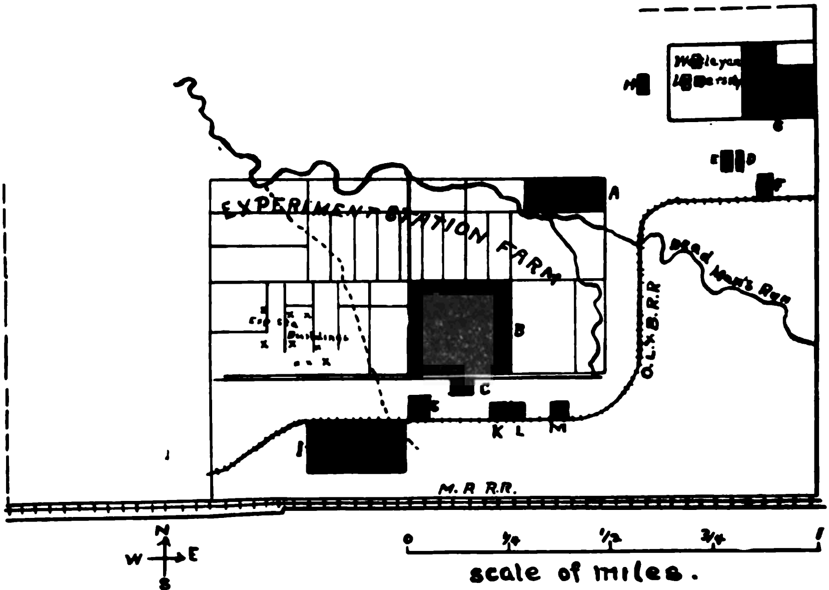
Before deciding that a field contains no inoculated plants, one should dig up and carefully examine a large number of the green and most vigorous plants. On the other hand, lack of complete inoculation should not be considered proven until a large number of the most yellow and unthrifty plants have been similarly treated. The yellow color of the plants is often due to some parasitic disease and not to lack of the necessary bacteria.

The author has failed in only two of over 100 alfalfa fields he has examined in Nebraska to find at least a few inoculated plants. In both of these exceptions the supply of available nitrogen was so abundant that all the plants were dark green in color and very vigorous in growth, thus rendering the search for inoculated plants unusually difficult.

OBSERVATIONS IN ALFALFA FIELDS IN NEBRASKA.

Lancaster County.—The oldest fields of alfalfa near Lincoln are those on the Experiment Station farm, two being indicated on the accompanying map as A and B. These were sown in the spring of 1895. The former and part of the latter have since been plowed up. In the spring of 1903, both of these fields as well as C on the south side of Holdrege Street and separated from A only by the roadway, as well as the west half of Block 77 (H) and Lot 1, Block 108 (D), University Place, were found fully inoculated.

The small field on Lot 1, Block 108, marked D on the map, had been seeded by the author in April, 1900, and a partial stand secured, no inoculation being tried. Lots 3 and 4 (E) were prepared similarly and seeded at the same time; but, altho they were given the same care, the alfalfa plants on these were nearly all dead by September. The previous history of the two areas had been somewhat different. D had been used as a garden, being manured yearly, while E had been kept continuously in corn without manuring and accordingly did not have the same supply of available nitrogen.



Map showing the location of the alfalfa fields of Lancaster County that are referred to in this article.

Early in April, 1903, E was plowed, harrowed several times to secure a firm seed bed, and sown with alfalfa. Before harrowing in the seed, about 100 pounds of inoculating soil from D was scattered over the south half of E. Then the uninoculated half was harrowed first in order to prevent the spreading of the inoculation by the harrow and the hoofs of the horses. The seed germinated well and a good stand was secured, equally good on both halves of the field. At the end of the third week in May, the plants were from three to five inches high and all of good color. One hundred plants were carefully removed from the extreme north (uninoculated) end and the same number from the south (inoculated) end. On only 5 of the first 100 plants were any nodules found, while 95 of the second had nodules. No distinct difference between the inoculated and the uninoculated plants was to be seen in the color, size, or vigor. A very heavy rain fell a few days after the above examination was made, half of the field being covered by water for a short time. Three weeks later another examination of both ends of the field was made but no uninoculated plants were found. The heavy rain had evidently spread the inoculation over the whole field. No difference was observed between the two ends from that time on.

On about the same day as E was sown, Mr. I. M. Clark sowed alfalfa on Block 122 (F), University Place, only one hundred yards from D but on another slope of the same ridge; accordingly no storm water from the latter could run over it. The field was in equally good condition and the seed bed was as well prepared. No inoculated soil was scattered on this, however. A good stand was obtained, but from the middle of June on the plants were of poor color and lacked vigor. Examinations made at various times failed to show any inoculated plants. In the spring of 1904 the stand on the field was rather thin and at the time of the first cutting, about the 1st of June, no inoculated plants were found. Immediately after the removal of the first cutting of hay, which was not more than one-third as heavy as that on E, the field was inoculated with soil from the latter. The second cutting seemed almost as heavy as that on E. An examination at this time showed no uninoculated plants, while the stand seemed to have much improved. Of course there had been no increase in the number of plants but each plant bore several times as much foliage as it had before the first cutting.

In the spring of 1904 Mr. I. M. Clark sowed to alfalfa the east end of the land belonging to the Nebraska Wesleyan University campus. The field formed the summit of a ridge, the highest part now constituting the Wesleyan athletic field. It had for many years been in cultivation to corn, sorghum, etc., and probably had never been manured. Adjoining this field on the west slope of the ridge was a considerable area of virgin prairie well supplied with native legumes.[1] In 1903 part of the field had produced a very heavy crop of sorghum hay while the rest had been in potatoes. The alfalfa came up well, an excellent stand being obtained, while the number of weeds was unusually small. From about the 1st of July on, the field was examined at frequent intervals. At that time it was as a whole a light yellowish green in color but there were very many spots where the plants were dark green and much taller and more vigorous than on the rest of the field. Nearly all of these spots had a more or less circular form with a diameter of from 10 inches to 2 feet. A very few were still larger. All the dark green plants examined from these patches bore nodules, while the yellow plants which formed the main portion of the field bore none. Here and there among the yellow plants, individual green ones were found and these bore nodules. As the summer advanced, the green spots increased greatly in number and size, many of them being from 6 to 12 feet in diameter by the middle of September. The following May, after growth had well started, it was found that the inoculated areas were still larger than in the previous autumn, many of them being 30 feet in diameter. They were still more or less circular in outline except where several had grown together. The first cutting was not more than half a crop, the uninoculated areas giving very little hay while the inoculated areas produced heavily. About a month later, when the field was ready to cut a second time, it was examined. The yellow areas had entirely disappeared, the whole field being dark green in color and the

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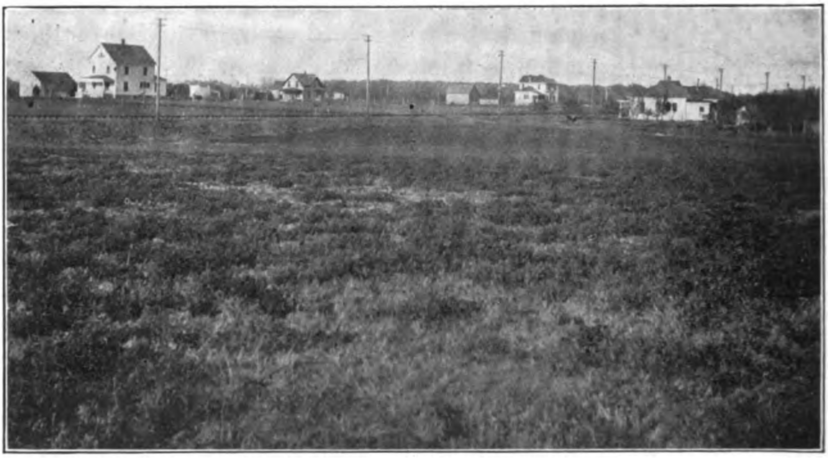
crop everywhere uniformly heavy. From that time on until part of it was plowed up in 1909, the field remained uniform.

A recent article in the Nebraska Farmer of March 2, 1910, by G. M. G. of Elk City, Nebr., describes a very similar spread of inoculation in the case of a field on high upland in Douglas County. The following extracts are from the article:

> "I will state first that our place lies in the extreme eastern part of the state (Douglas county) and at about the highest point between the Elkhorn and Missouri valleys."
>
> "The first piece of alfalfa was seeded early in the fall of 1904. From continuous cropping the soil was low in productivity but was given a good coat of manure before seeding. No artificial inoculation was given this piece. A good stand was secured and it wintered perfectly and grew well the next spring until it was about six inches high when it began turning yellow, excepting small spots here and there which remained dark green and vigorous. These green spots showed that they had become inoculated by natural means and they gradually spread out, but not until the following spring did they claim the whole field. Very little hay was obtained until that year, but from that time on until 1909 it showed a thick stand and did fine."
>
> "I have seen seedings in this locality where inoculation has taken place by natural means almost as quickly, but I have seen more of them that haven't and certainly wouldn't advise anyone to try it without inoculating unless they wish to gamble on the chances of losing the use of their land for about one year and maybe the seed also."

In the spring of 1907, a large field, the Hubbel & Nilson tract, lying two blocks south of the Experiment Station farm and marked I on the map was sown to alfalfa As it has since east corner, where a small draw crosses it, leaving this corner above the reach of water flowing thru the draw. The accompanying photo shows this. An old alfalfa field, J, had been just northeast of Field I, and before the grade for the railway was thrown up in 1905 part of the run-off from this old alfalfa field on its way to the draw had crossed this corner of Field I. This is the probable explanation of the differences in growth between the alfalfa on this corner and on the rest of the east half of the field.



Photograph of alfalfa field I, taken April 22, 1910, showing northeast portion of field. The man is standing in the bottom of the draw. Between the draw, the road, and the railway lies the small triangular area in which all the alfalfa plants were inoculated from the first time of observation. The source of this inoculation was the field diagonally opposite, which is now separated from I by the railway grade.

The field had been in continuous cultivation for 30 or 40 years, with many heavy applications of barnyard manure. In 1906 it had been in sorghum, which had been allowed to mature seed and much of this seed had been left on the ground and germinated among the alfalfa in 1907. The volunteer sorghum on the west end of the field was much thicker, and its growth much more vigorous, than on the other end, but there was, however, no sharp line of change, it being especially rank near the northwest corner, where heavy applications of manure had been made the previous year, and becoming gradually poorer toward the east. A thick uniform stand of alfalfa was secured on all parts of the field, but after warm weather set in the growth on the different parts was far from uniform. On the west end there were many spots where the growth of alfalfa and sorghum was very vigorous, while on the east end, except on the northeast corner, shown in the photograph, the growth of both was weak. On this corner of the field the growth of alfalfa was everywhere vigorous while that of the sorghum was as poor as on the rest of the east end. On the west end the sorghum was so thick and its growth was so vigorous that in order to protect the alfalfa this part was mown near the end of June as well as several times later during the season, while on the east end the sorghum was neither sufficiently thick nor vigorous to seem to need cutting before it was gone over about the middle of August.

From June on, the differences between the inoculated and the ordinary uninoculated plants could be seen on both ends of the field. On the west end, even before the first mowing, there were many large patches where the plants were all inoculated, and between these patches were many inoculated individual plants. Not all of the dark-green plants in the green patches, however, bore nodules. All the plants on the northeast corner were inoculated, as were also those on the lower part of the slope on the northwest side of the draw this evidently being due to water having stood in the draw for some time after a heavy rain. From this green margin of the draw the number of inoculated plants thinned out rapidly until at a short distance they were no more numerous than on the rest of the east end. No large patches of inoculated plants were found on this end, but there were many individual inoculated plants. After each successive mowing, the west end assumed a much more uniform appearance, the uninoculated areas becoming smaller while a distinct line with dark green plants on one side and yellow or yellowish green plants on the other marked the east boundary of the mown area.

On August 3 a careful search for inoculated and uninoculated plants was made on the west end of this field as described above (page 34).[1] On the same day a typical uninoculated area 96 feet long by 3 feet wide was selected on a gentle slope where there was little chance of drainage from one part of it to another. This was marked off by means of wooden pegs into 32 plats 3 feet by 3 feet. Part of them were given different treatment, as indicated below, the others being left untouched. Those that were weeded had every plant other than alfalfa pulled up by the roots, thus somewhat disturbing the surface soil. To avoid this disturbance of the surface with the consequent aeration of the soil and the formation of light mulch, all the weeds on Plats 5 and 7 were clipped off level with the surface by means of scissors. The inoculated plats were separated from those treated but not inoculated by four untreated plats and from one another by untreated plats. The inoculation was effected by scattering over the surface of each square about five pounds of soil from the northeast corner of the field. On August 10 the plants on every treated plat was counted. Part of these data was lost. On this date only four plants, judging from the color and vigor, were inoculated, one each on Plats 1, 3, 13, and 30.

On August 19, a day or two after the field had been mown and raked, the plats were examined again. The mower knife had been set so high that the tops of only the inoculated plants, together with the weeds, had been cut. Every plat showed the imprint of the wheels of the mower or of the horses' feet. The plats which had been only weeded, clipped, or raked showed very slight improvement over the untreated plats, while those that had also received a dressing of the inoculating soil showed a distinct improvement. Just before frost occurred in the autumn, the form of the plats which had been treated with the inoculating soil could be made out easily at a distance of fifty yards, while those of the others could not. During the autumn the uninoculated plants died out rapidly. The large number which thus disappeared is evident from the count made on April 4, 1908. The loss varied from 50 to 97 per cent of the stand of August 10, 1907. The growth at the time was not yet sufficient to indicate how many of the plants were inoculated. At the time of the second cutting of hay in 1908 all uninoculated plants had disappeared. Since that time the field has become more uniform in appearance, the isolated plants growing larger than those closely crowded together, but a large part of the east end of the field still produces only a partial crop.

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[1] Article by Alway and Pinckney.

Plat No.	Treatment on Aug. 3, 1907	No. of plants Aug. 10, 1907	No. of plants Apr. 4, 1908	Appearance Aug. 19, 1907
1	Weeded	222*	106	Slightly better than untreated plats and surrounding growth
3	Clipped	243*	9	
5	Weeded	234	44	
7	Clipped	350	11	
9	Raked		14	
11	"		40	"
13	Weeded and raked	*	80	"
15	" " "		13	"
20	Treated with inoculating soil		130	Somewhat better than above
22			63	
24	Treated with inoculating soil and raked		118	"
26	Treated with inoculating soil and raked		64	"
28	Weeded and treated with inoculating soil	417	148	Much better than 20, 22, 24, and 26
30	Weeded and treated with inoculating soil	447*	160	
32	Weeded and treated with inoculating soil and raked		135	"
34	Weeded and treated with inoculating soil and raked		44	Like 28-32 but only a small number of plants

*One inoculated plant on plat on Aug. 10, 1907.

Several other small fields—K, L, M,—near the Experiment Station farm but situated so that there was no chance for ino was disappointed in the light yields of hay and yet did not care to plow and sow again.

Furnas, Harlan, Phelps, and Kearney Counties.—In the latter part of June, 1903, the writer wheeled from Arapahoe to Kearney by way of Oxford, examining every field of alfalfa along the road. Between Arapahoe and Oxford in the Republican valley, alfalfa was even at that time the most important crop, while on the high land between Oxford and Kearney some eight or ten fields were seen. Some forty old fields in the valley were examined and all found to be inoculated, while in only about half of those on the high land did the inoculation seem to be complete. Only two newly sown fields were seen, both being in the Republican valley. The one was part of an old alfalfa field which had been resown. The plants were only about two inches high, but every plant bore nodules. The other field was on the bank of a creek. The plants in this were about as large as in the former and all nearest the creek were inoculated while those farther away were uninoculated. The explanation of this probably is that the creek rising above its bank had inoculated the lower side of the field, the upper edge of the inoculated area seeming to be practically a contour line.

Buffalo County.—On June 23, 1903, the Watson ranch west of Kearney, the pioneer alfalfa farm in Nebraska, was visited. The old fields in the valley were all inoculated, and Mr. N. C. Dunlap, the manager of the ranch, had been shipping soil to Illinois and New York for inoculation purposes. In a newly sown field on the crest of the ridge to the east of the buildings, every plant was found inoculated. The explanation of this was that Mr. Dunlap, to make sure of inoculation, had, before sowing the seed, given the field a light dressing of manure from alfalfa-fed cattle.

In the early years of alfalfa production on the Watson ranch it was usually necessary to seed a field twice before getting a

Hall County.—On June 24, 1903, the Taylor ranch near Abbott station, northeast of Grand Island, was visited. Several hundred acres of alfalfa had been sown in 1902 on virgin soil on low sand hills. A perfect stand had been obtained and the alfalfa did well the first season but at the time of the inspection in 1903 it was looking rather sickly, nearly all the plants being yellowish green in color. These were found uninoculated, while only an occasional dark green inoculated plant could be found. On the same ranch there were several hundred acres of old alfalfa, all inoculated and all doing well. One old field which had been killed out had been plowed up and reseeded in the spring. All the young plants on this were found inoculated.

Hitchcock, Dundy, Chase, and Perkins Counties.—In August and September, 1903, many fields near Wauneta and Champion in the Frenchman valley and between Culbertson and Benkelman in the upper Republican valley, were examined. In all of these the plants were found inoculated, but on many fields in the Republican valley the stand was thin, as tho most of the plants had succumbed before becoming inoculated. In the whole distance between Culbertson and Benkelman only two good alfalfa farms were seen. One of these was above Max, while the other was on Indian Creek just where it enters the Republican valley. The former was entirely in the valley but the latter was partly on the hillside. While the growth was much shorter on the hill, all the fields were inoculated and showed a good stand.

In May, 1907, Mr. J. S. Campbell of Imperial plowed a small field of virgin prairie, worked it up to make a fine seed bed, and sowed alfalfa in drills about 12 inches apart. This was kept hoed and weeded like a vegetable garden thruout the summer. The first week in September, the plants were in bloom and were being cut for feed. All were vigorous and dark green in color and gave every evidence of being inoculated. A careful search for nodules was made by Mr. Campbell and the author without finding any, tho we found a supply of inoculating soil in a field not far distant. This field had been sown to alfalfa the previous year and at the time of inspection the plants were in seed. A careful search revealed that in the part of the field where the stand was thickest and the plants largest all the plants bore nodules, while on much of the rest of the field most of the plants carried no nodules.

A field four miles east of Imperial had been sown broadcast in the spring of 1907, and in September there was a good stand of plants, about one-third of them bearing nodules. The inoculated plants were readily recognizable, they being larger and darker in color, altho all the plants were in healthy condition.

What is probably one of the most isolated valley farms of alfalfa occurs on the upper part of the Stinking Water valley in Chase County. The fields belonging to Mr. Inman were examined in September, 1907, and found to be thoroly inoculated. A newly sown field just below these in the valley and belonging to Mr. McCoy was found to be fully inoculated.

In November, 1907, two fields on the H O ranch near Madrid, Perkins County, showed a thin stand of fully inoculated plants. The seed had been sown the previous year.

Dawes County.—In August, 1903, a small field of fully inoculated young plants was found between Crawford and Adelia. The field had been sown that spring and had been flooded several times by storm waters from the adjacent hills, embankments having been thrown up in order to keep the storm waters on the field until they could soak into the soil. This flooding accounted for the full inoculation.

Other Counties.—Inoculated fields have been found in various other counties of the State, no field having been found which was not partly inoculated except the two already referred to. Fields which are only partly inoculated are evidently found but rarely after the early part of the second season, the plants that do not become inoculated dying out.

SOURCES OF INOCULATION.

The establishment of satisfactory stands of alfalfa in all parts of the state and the finding of nodule-bearing alfalfa plants in practically all newly sown fields examined indicate that the proper bacteria in small numbers are either carried with the seed or are already present in the soil. It has been most commonly assumed that the bacteria carried by the seed constitute the source of the inoculation of the few scattered inoculated plants almost always found.

The agent that has been most relied upon in Nebraska for the inoculation of fields in a district where alfalfa is already established is the wind. As is well known large amounts of soil are carried by the high winds, especially by those from the southwest. If the soil thus transported carried the bacteria, we should expect to find all the fields to the immediate northeast of the Experiment Station farm fully inoculated, as large fields of alfalfa have been grown on this farm for the past fifteen years. Yet the fields less than half a mile distant, as described above, have been shown to need inoculation. In view of this it seems probable that the wind is unimportant as a carrier of inoculating soil, the bacteria being killed by exposure to the bright sunshine characteristic of Nebraska. The soil transported by the wind has been dried and exposed to the sun often for many days. The winds carry the soil chiefly during the daytime, thus exposing it in a fine state of division to the sunlight. Even after the transported soil has been deposited on the surface of other fields, it may still be exposed for several days to intense sunlight before a rain carries the accompanying bacteria down into the soil beyond the reach of the light.

Water is the most effective natural means for the dissemination of the bacteria. A heavy rain falling on sloping ground more rapidly than it can be absorbed by the soil will flow over the surface of an inoculated alfalfa field, carrying the inoculation to all fields traversed. All newly sown fields receiving run-off from an inoculated field will be found fully inoculated. The inoculation of new fields on river bottoms exposed to occasional inundation is to be attributed to the same cause, some of the waters having traversed inoculated fields. Where only part of the plants are inoculated a flooding of the field may be counted upon to inoculate all of the others. To this is probably due the usual lack of any necessity of intentional inoculation in the case of irrigated fields.

The soil carried on farm implements from inoculated fields may serve to inoculate other fields. In the case of a partially inoculated field the mower, the rake, and the hoofs of the horses serve to spread the inoculation. The more frequently the young stand on such a field is cut, the more rapidly is the complete inoculation effected. The complete inoculation of a field usually observed after the removal of the first crop of hay is thus to be explained.

The droppings from alfalfa-fed animals in fields which are later sown to alfalfa may account for the occurrence of the green patches observed in some newly-sown fields.

Sweet clover, as it occurs widely scattered as a weed along the roadsides and railways, seems almost inoculated. Nowhere has the author found uninoculated plants. It is quite probable, however, that where the sweet clover is sown as a field crop it will show only part of the plants inoculated during the early part of the first year. Any of the above-mentioned methods will serve to carry the bacteria from the soil where the inoculated sweet clover is growing to uninoculated alfalfa plants. The bacteria associated with some of the native legumes may, as has been suggested by various writers, be capable of inoculating alfalfa.

Old alfalfa fields plowed up and reseeded, as well as those properly dressed with soil from inoculated fields, will show complete inoculation. There are, however, instances known where soil carrying an abundance of nodules has, when allowed to dry out and remain in this condition for some time, failed to cause any inoculation. In Bulletin 313 of the New York Experiment Station two instances are mentioned. In one of these the bag of soil was held in a dry place for three months before being sown, and in the other, one year. The author, early in July, 1903, failed to reveal a single inoculated plant. The inoculation of the field was then secured by treating it with soil from a roadside patch of inoculated sweet clover.

Manuring a field for alfalfa insures its inoculation in case the manure is from alfalfa-fed animals. Even if no alfalfa has been used in feeding the animals, the manure will still be an important help to the young plants, as it supplies them with available nitrogen and thus enables them to survive longer than they would without. The longer the plants survive, the greater is their chance for inoculation by some of the various means mentioned above.

SUMMARY AND CONCLUSIONS.

Alfalfa sown on fields subject to occasional inundation or on upland fields receiving storm waters from well-established alfalfa fields may be expected to show complete inoculating from the first. On upland fields receiving no run-off from old fields there may be expected to be found a considerable number of inoculated plants. These may be identified both by their color and vigor and more surely by the examination for nodules on their roots. On upland fields on which alfalfa has been grown before in very recent years or on which manure from alfalfa-fed animals has been scattered, complete inoculation may be expected. On farms in which there are already fields of alfalfa, the newly sown fields have several sources of more or less complete inoculation—the wash from the old fields, the carrying of the inoculated soil by farm implements, and the droppings from the alfalfa-fed farm animals pasturing or working in the field. For this reason, other things being equal a farmer already having alfalfa is more likely to get a good stand than his neighbor who has not. Some upland fields will, without any attention to their inoculation, give satisfactory stands, or, after the plants have been growing long enough to show that they are not all inoculated, by dressing it with the inoculating soil. In the latter case, this soil, which usually can be found in some part of the newly sown field or obtained from some adjacent old alfalfa field or from roadside patches of sweet clover, should be scattered over the field just before a rain.

THE DETERMINATION OF NITROGEN IN DRIED UNGROUND CEREALS

By F. J. Alway and E. S. Bishop

For some years past this laboratory has had to make, for the Department of Agronomy, a very large number of determinations of nitrogen in winter wheat. During the past three summers it has been desired that the results be gotten out with all speed, so that full data in regard to the grains harvested in July might be available before time for seeding, which is usually about the middle of September. Extreme accuracy in analysis was not essential, but it was necessary to be able to distinguish with certainty between samples with a medium and those with either a high or a low nitrogen content, the percentage on a dry basis ranging from below 2 to over 4 per cent. After some preliminary work it was found that by not grinding the kernels a great saving in time could be effected without seriously lessening the accuracy of the determinations. The various stages in the analysis where time may thus be economized will be so evident to anyone having had occasion to make wheat analyses that these do not need to be mentioned here.

Requests have been received from other laboratories for a detailed description of the method, and in order to show its accuracy compared with the ordinary method we have made the determinations reported below in Tables II, III, and IV. While the method has not been used in this laboratory with any other cereal than wheat, we have included in these analyses a sample of rye and two samples of oats in order to test its applicability in the case of other cereals.

The Method.—The grain, freed of broken and badly shrunken out, allowed to cool, and weighed. They are then returned to the oven and after two hours further drying are weighed again. If the loss in weight during the last two hours has been slight and the total loss in weight by all the check samples is normal, it is assumed that all the samples are dried; otherwise the heating is continued two hours longer. Then the weighing bottles are quickly removed from the oven, stoppered at once, and allowed to cool in desiccators. From each dried sample a 1-gram portion of wheat is weighed out, transferred to a Kjeldahl flask, and the nitrogen determined as in the ordinary method.

When entire kernels are used, it is often necessary, in order to get approximately one gram, to either split a kernel or substitute a lighter kernel for one of those first placed on the scale pan. The latter has been found the preferable method, and it has proved to be a simple matter to thus get within .0020 gram of the desired weight. As this difference in the weight of the wheat used would make a difference of less than .005 per cent of nitrogen, it is so close that it is safe in calculating to assume that a whole gram has been used. Thus, assuming that exactly one gram of wheat has been used, the error is shown in the following:

Weight of wheat used.	Actual per cent of nitrogen.
1.0000 gram	2.2400
1.0020 gram	2.2355
0.9980 gram	2.2445

Accuracy of Sampling.—In Table I are given the results of the nitrogen determinations in the case of two samples of unground undried wheat. The one sampling was very uniform, all the kernels being plump, while the other was a mixture of plump and badly shrunken kernels, it being from a field in which parts of the table indicate that in the case of the uniform sample as concordant results are obtained from the unground as from the ground, but that in the case of the uneven sample the results are not quite so concordant in the case of the former as in that of the latter. It is evident that with uniform samples or with uneven samples from which the smallest and most shrunken kernels have been removed by sifting, strictly representative 1-gram portions may be obtained without the necessity of grinding.

TABLE I.—*Agreement of nitrogen determinations of ground and unground wheat.*

Analysis No.	Sample uniform			Sample not uniform		
	Ground	Unground		Ground	Unground	
		Series I	Series II		Series I	Series II
1	2.14	2.20	2.14	2.28	2.20	2.20
2	2.08	2.14	2.14	2.39	2.20	2.31
3	2.14	2.18	2.11	2.43	2.38	2.25
4	2.22	2.20	2.21	2.43	2.28	2.31
5	2.17	2.20	2.18	2.38	2.31	2.32
6	2.15	2.11	2.15	2.38	2.25	2.34
7	2.10	2.13	2.18	2.41	2.31	2.22
8	2.11	2.21	2.11	2.39	2.38	2.42
9	2.08	2.18	2.11	2.31	2.41	2.31
10	2.08	2.11	2.13	2.34	2.34	2.38
11	2.20	2.11	2.10	2.31	2.22	2.34
12	2.11	2.20	2.11	2.37	2.29	2.43
Average	2.14	2.16	2.14	2.37	2.30	2.32
Maximum departure from average	.08	.05	.07	.09	.11	.12

COMPLETENESS OF THE DRYING.—From Table II it will be seen that nearly all the moisture in the unground kernels is lost during the first four hours, but that in the case of the wheat and rye small amounts continue to be lost, even up to the 28th hour. With the oats the drying is practically complete at the end of the 8th hour. The amount of moisture retained after six hours, drying is so small that the error occasioned by assuming that the sample is water-free amounts to less than .03 per cent, as shown in Table III. The percentages in this table have been calculated from the data given in Tables II and IV.

AGREEMENT OF DUPLICATE DETERMINATIONS.—In Table IV are shown the results of five individual analyses of each of the samples referred to in Table I. All had been dried at 110° for 28 hours. The results for all except the sample of light oats are concordant.

From a bottle holding about 50 grams of very uniform wheat, twelve 1-gram samples were poured out, one after the other. Another sample of wheat in which about one-third of the grains were badly shrunken was treated in the same manner. The results in the case of the former ranged from 2.20 to 2.39, with an average of 2.30 per cent, while those of the latter ranged from 2.36 to 2.60, with an average of 2.53 per cent. The maximum departures from the average were .10 and .17 per cent respectively. In neither case were the results as concordant as where the 1-gram portions were removed from the large sample by means of a spoon and forceps. When the whole sample weighed only from 3 to 10 grams, quite as concordant results were obtained by the one method as by the other.

TABLE II.—*Rate of loss of water from unground kernels when dried at 110° C.*

Cereal	Sample	Per cent of moisture lost in successive intervals								Total loss in 4—28 hrs.
		0—4 hrs.	4—6 hrs.	6—8 hrs.	8—12 hrs.	12—16 hrs.	16—20 hrs.	20—24 hrs.	24—28 hrs.	
Wheat I..	1	10.60	.44	.34	.26	.15	.27	.14	.05	1.65
“ I	2	10.65	.41	.38	.22	.15	.20	.05	.10	1.51
“ I..	3	10.96	.36	.36	.21	.14	.25	.12	.05	1.49
“ I..	Av.	10.74	.40	.36	.23	.15	.24	.10	.07	1.55
Wheat II.	1	10.84	.36	.32	.17	.17	.22	.06	.08	1.38
“ II.	2	10.56	.39	.32	.13	.16	.21	.05	.14	1.40
“ II.	3	10.23	.31	.36	.27	.19	.36	.11	.09	1.69
“ II.	Av.	10.54	.35	.33	.19	.17	.26	.07	.10	1.49
Rye	1	10.93	.42	.26	.26	.08	.24	.07	.11	1.44
“	2	10.35	.51	.50	.24	.13	.18	.07	.08	1.71
“	Av.	10.64	.46	.38	.24	.11	.21	.07	.10	1.57
Oats I....	1	10.17	.16	.18	.07	.03	.12	—.02	—.03	.51
“ I....	2	10.17	.03	.37	.15	.00	.09	.00	.00	.54
“ I....	3	10.16	.12	.10	.09	.00	.13	.02	.00	.46
“ I....	Av.	10.17	.10	.22	.10	.01	.12	.00	—.01	.50
Oats II...	1	9.95	.23	.18	.08	.05	.09	.05	.00	.68
“ II...	2	9.88	.21	.27	.12	.00	.18	.04	.00	.82
“ II...	3	9.82	.12	.23	.02	.00	.18	.01	—.03	.53
“ II...	Av.	9.88	.19	.23	.07	.02	.15	.03	—.01	.68

TABLE III.—*Percentage of nitrogen that would be found in grain dried for different lengths of time at 110 ° C.*

Cereal	4 hrs.	6 hrs.	8 hrs.	12 hrs.	16 hrs.	20 hrs.	24 hrs.	28 hrs.
Wheat I..............	2.16	2.17	2.17	2.18	2.18	2.19	2.19	2.19
Wheat II....	2 36	2.37	2.38	2.39	2.39	2.40	2.40	2.40
Rye	2.36	2.37	2.38	2.39	2.39	2.40	2.40	2.40
Oats I.	1.72	1.72	1.73	1.73	1.73	1.73	1.73	1.73
Oats II...	2.14	2.14	2.15	2.15	2.15	2.15	2.15	2.15

TABLE IV.—*Agreement of duplicate determinations of nitrogen in unground cereals dried 28 hours at 110 ° C.*

Cereal	Per cent nitrogen						Maximum departure from average
	1	2	3	4	5	Average	
Wheat I.......	2.20	2.20	2.22	2.17	2.18	2.19	.03
Wheat II.............	2.39	2.42	2.39	2 41	2.39	2.40	.02
Rye	2.42	2.38	2.38	2.42	2.38	2.40	.02
Oats I.................	1.70	1.72	1.72	1.72	1.79	1.73	.06
Oats II.	2.17	2.11	2.27	2.18	2.04	2.15	.12

THE COLOR AND ASH CONTENT OF DIFFERENT GRADES OF NEBRASKA FLOUR

BY F. J. ALWAY AND V. L. CLARK

Up to the present time there are no chemical tests known by which the bread making qualities of a flour may be definitely ascertained. In order to determine these it is necessary to convert a sample of the flour into bread, using as a standard a flour of known bread making value. However, the most satisfactory results are obtained when the flour is subjected to both baking and chemical tests. Among the latter, the determination of the ash probably gives the most definite information because it indicates the commercial grade of the flour.

No definite standards for flour have been adopted by chemists, millers, or dealers. Commercially the flour is graded as first and second patent, straight grade, first and second clear and "Red dog." The last mentioned is used but little for human food. "By mixing various amounts of the different standard grades of flour, large numbers of flours with different trade names are obtained. Many of the brands of flour sold on the market are produced by blending different amounts of the patent and clear grades of flour."[1]

The percentage of ash in both the different grades of flour and the shorts and bran obtained by the roller milling process are indicated in Table I, which is taken from Bulletin 101 of the Office of Experiment Stations. While the percentages of ash in the different grades will vary more or less from mill to mill and for different lots of wheat, they will not be far from those given in the table.

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[1] Snyder, Bul. 101, Office of Experiment Stations.

TABLE I.—*Percentages of ash in different grades of flour and in the by-products and approximate percentages of the total weight recovered in the products.*

	Ash	Recovered
	Per cent	*Per cent*
First patent flour	0.37	60.0
Second patent flour	0.42	
Straight or standard patent flour	0.50	72.0
First clear grade flour, or bakers'	0.80	12.0
Second clear grade flour, (low grade flour)	1.75	.5
"Red dog" flour	3.48	2.0
Shorts	4.56	11.0
Bran	6.06	14.5

The color has also been used in the grading of flour. The high grade flours contain very few particles of bran and are therefore of a white color with a tinge of yellow. The intensity of the yellow tint varies greatly. The lower grades of flour contain more particles of bran and have a darker color with a grayish tinge. The amounts of yellow coloring matter in the different grades of flour obtained from the same wheat appear to be about the same.

The most characteristic property of the flours made from the hard winter wheat grown in Nebraska is their unusually deep yellow color. This color, however, is not indicative of an inferior quality, but it is not attractive to the purchaser. This intensity of color serves to partly obscure the differences between the different grades. The difference becomes much more apparent after bleaching, the bright yellow or butter yellow patent becoming white while the lower grade bakers' becomes gray. For this reason the bread from a bleached high grade Nebraska flour is more inviting in appearance than that from the unbleached flour. Bread from a bleached low grade flour, on the other hand, has a most uninviting appearance. From this it is easy to understand why millers bleach their high grades and place their low grade flour on the market in an unbleached condition.

The *straight*, or standard patent, flour is made up of the first and second patents and the first clear. This is the ordinary bread flour most commonly placed upon the market. The first clear is

In connection with an investigation of bleached flour during 1906 and 1907, samples of both bleached and unbleachd flour were secured from a large number of Nebraska mills. Requests were sent to the different mills for samples of three grades—patent, straight, and bakers'. The ash was determined in eleven sets of these samples. The color also of each sample was determined by a modification of Pekar's method. Wedge-shaped masses of flour were prepared on small rectangular plates of window glass, using a nickel flour slick. After all the samples that were to be compared with each other had been thus prepared, using a separate piece of glass for each, they were dipped below the surface of water, allowed to remain one minute, withdrawn, well drained, placed in an oven at 205° F. and heated half an hour.

TABLE II.—*Relation of color of flour to ash content and to grade reported by miller.*

Mill No.	Grade reported by miller	Ash	Color
		Per cent	
1	Patent	.37	Clear yellowish white.
	Straight	.40	Butter yellow.
	Bakers'	.53	Yellowish gray.
2	Patent	.34	Clear yellowish white.
	Straight	.35	Yellowish white with trace of gray.
	Bakers'	.51	Yellowish gray.
3	Patent	.36	Clear yellowish white.
	Straight	.42	Deep yellow with gray tint.
	Bakers'	.60	Yellowish gray.
4	Patent	.36	Clear yellowish white.
	Straight	.46	Yellow with gray tint.
	Bakers'	.56	Yellowish gray.
5	Patent	.40	Clear light yellow.
	Straight	.42	Yellowish white with no trace of gray.
	Bakers'	.50	Yellowish gray.
6	Patent	.33	Clear butter yellow.
	Straight	.47	Yellow with gray tint.
	Bakers'	.52	Yellowish gray.
7	Patent	.37	Clear yellow.
	Straight	.44	Clear butter yellow.
	Bakers'	.66	Yellowish gray.
8	Patent	.30	Clear white with very faint yellow tint.
	Straight	.37	Clear white with more yellowish tint than the preceding.
	Bakers'	.54	Yellowish gray.
9	Patent	.42	Clear light yellow.
	Straight	.46	Light yellow with gray tint.
	Bakers'	.68	Gray.
10	Patent	.38	Clear light yellow.
	Straight	.43	Light yellow with gray tint.
	Bakers'	.71	Yellowish gray.
11	Patent	.35	Clear butter yellow.
	Straight	.37	Yellowish white with trace of gray.
	Bakers'	.55	Yellowish gray.

Patent	Highest per cent of ash	.42
	Lowest per cent of ash	.30
	Average per cent of ash	.36

A comparison of the ash content of these 33 samples of flour with the data given in Table I will show that none of them is below the grade reported by the millers. In all cases the bakers' grade shows more ash than the straight grade from the same mill and the straight shows more ash than the patent from the same mill. The same statement does not hold true when the samples from different mills are compared. The colors correspond to the grades, the bakers' grade in all cases showing a more or less gray tint. Most of the samples of the straight grade show a trace of gray, while none of the patents do. It is evident that these eleven sets may be considered strictly representative of the three grades requested. As these sets were selected by chance from the samples sent in by over twenty mills, it is safe to conclude that the large collections of flours dealt with in Bulletin 102 of this Experiment Station were as truly representative as could be desired.

THE RELATION OF THE BREAKING STRENGTH OF HOG BONES TO THE COMPOSITION OF THE ASH

BY F. J. ALWAY AND W. L. HADLOCK

In Bulletin 107 of this Station it has been shown that there is a close relation between the nature of the food supplied to growing hogs and the strength of their bones, and, further, that an increase in the strength of the bones is not accompanied by any distinct increase in their length, circumference, or volume. The per cent of mineral matter, or bone ash, the specific gravity, and the wall thickness increase with the breaking strength.

In order to determine whether any change in the composition of the bone ash accompanies the change in the percentage of mineral matter and in the strength of the bones, we analyzed samples of ash from both the strongest and the weakest bones reported in Bulletin 107.

The ash used as representative of the weak bones was a composite of that from the right and left femur, tibia, humerus, radius, and ulna of the lot of four hogs having the weakest bones, while that used as a representative of the strong bones was a similar composite from the lot of four hogs with the strongest bones. The first lot of hogs had been fed 100 per cent corn-meal, while the second had received 10 per cent bone-meal and 90 per cent corn-meal. The bones were reduced to a fine state of division and dried. Those of the first lot were soft and easily pulverized, while the others were very hard and with difficulty reduced to a powder. In order to replace the carbon dioxide lost during the destruction of the organic matter, the samples were treated with a saturated solution of ammonium carbonate, dried and heated in a muffle, kept below redness, to constant weight. Portions of the ash so prepared were dissolved in dilute hydrochloric acid for the determination of calcium, magnesium and phosphoric acid.

	Weak bones.	Strong bones.
Average per cent of mineral matter in green bones	25.4	37.2
Average specific gravity of green bones	1.167	1.346
Average wall thickness of green bones	2.8 mm.	4.1 mm.
Average breaking strength of green bones	702 lbs.	1505 lbs.
Composition—		
Calcium oxide, CaO,	52.47%	52.98%
Magnesium oxide, MgO,	1.24%	1.05%
Phosphoric oxide, P_2O_5,	41.61%	40.93%
Total constituents determined	95.32%	94.96%

Both lots had practically the same composition, thus indicating that the nature of the food has no effect upon the relative proportions of the different constituents of the mineral matter of bones.

THE NITROGEN CONTENT OF INOCULATED AND UNINOCULATED ALFALFA PLANTS.

BY F. J. ALWAY AND R. M. PINCKNEY

Shutt* has very recently reported the analyses of two samples of alfalfa hay produced in 1908 on an Experimental Farm at Lacombe, Alberta. One sample was from a plat which had been thoroly inoculated, while the other was from an adjacent uninoculated plat. The yields had been at the rate of 7,200 and 2,560 pounds respectively. There was a marked difference in the proportions of nitrogen, the sample from the inoculated plat containing 2.8 per cent and that from the other only 2.5 per cent,

The above is in accord with the results obtained at this Station in 1907 and 1908. We employed plants from the same field, however. For the analyses alfalfa plants were obtained from a large field which lies two blocks south of the Experiment Station farm, it being marked on the maps as the Hubbel & Nilson tract. This field had been sown to alfalfa in the spring of 1907 and an excellent stand of plants obtained. At the time the samples were taken in 1907, the number of alfalfa plants per square yard varied from 150 to 450. On the east half of the field a great majority of these plants were uninoculated. One hundred uninoculated plants, including both the above-ground portion and the root to a depth of nine inches or more, were collected, carefully washed free of adherent soil, divided into root and stalk, dried, weighed, and analyzed. The same number of inoculated plants was treated in the same manner. The results, which are shown in the table below, were so unexpected that fresh collections of roots were made eleven days later. On the second occasion, three lots of 30 each in the case of the uninoculated plants were collected on three different parts of the field, and two lots of ten each of inoculated plants from the same parts of the field. The result from these are given below. In 1908 the plants were collected early in June, just before the first cutting for hay, fifty of each kind being secured from the east end of the field.

In selecting the inoculated plants, those of a healthy green color were carefully removed from the ground by means of a spade, and the soil detached from the roots by washing in a pail of water. After the soil had been washed from the roots, if no nodules were found attached the plant was rejected. In more than nine cases out of ten, however, a plant selected on account of its color was found to have nodules. It is probable that the other green plants were inoculated and that their nodules had been detached in removing them from the ground. The plants selected on account of their color as uninoculated ones were treated similarly, but in the case of none of these were nodules found attached to the roots. The plants analyzed were typical in size of the two kinds, the dark green and the yellowish green. The inoculated plants were much larger and more vigorous than the uninoculated. The leaves of the former were dark green in color, while those of the latter were a light yellowish green. The roots of the inoculated plants were much larger than those of the uninoculated.

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*Annual Report of the Experimental Farms of the Dominion of Canada for 1909, page 159.

Weight and nitrogen content of inoculated and uninoculated alfalfa plants.

Date of collection	Inoculated or uninoculated	No. of plants collected	Average weight for each plant		Per Cent Nitrogen	
			Stalks and leaves	Roots	In stalks	In roots
1907			*Grams*	*Grams*		
Aug. 3	Inoculated	100	0.1789	0.1066	2.48	1 91
Aug. 3	Uninoculated	100	0.0289	0.0279	1.14	.95
Aug. 14	Inoculated	10	....	0.1476	....	1.36
Aug. 14	Inoculated	10	....	0.0551	....	1.88
Aug. 14	Uninoculated	30	....	0.0161	....	.96
Aug. 14	Uninoculated	30	.. ..	0.0200	. . ...	.97
Aug. 14	Uninoculated	30	.....	0.0184	....	.94
1908						
June 4	Inoculated	50	18.2200	4.8800	2 34	1.90
June 4	Uninoculated	50	0.3672	0.3860	1.77	0.76

The roots and stems of the inoculated plants were not only from three to fifty times as heavy as the corresponding parts of the uninoculated plants but they also contained about twice as high a proportion of nitrogen.

The above differences in nitrogen content might be made the basis of a method for distinguishing between inoculated and uninoculated plants were it not such a simple matter for any farmer who has once actually seen alfalfa nodules to distinguish between inoculated and uninoculated plants.

ON THE OCCURRENCE OF PRUSSIC ACID IN SORGHUM AND MAIZE

By F. J. Alway and R. S. Trumbull

In Bulletin 77 of this Station there appeared a full account of the presence of prussic acid in sorghum plants and of its relation to the poisoning of cattle by sorghum. Since that time many have felt inclined to attribute the deaths of cattle from so-called "cornstalk disease" to the same poison.

Dr. Avery while Chemist of this Station tested many samples of cornstalks from fields in which cattle had died, as well as the stomachs of the dead animals, without finding any evidence of this poison.

In 1903, Bruennich* of Australia reported finding prussic acid in Indian corn as well as in sorghum and made quantitative determinations of it in each. He also found that the more abundant the supply of available nitrogen in the soil, and consequently the more luxuriant the growth of the sorghum, the higher was the proportion of prussic acid.

In the summer of 1907, samples of corn plants from both fertile and impoverished fields were tested at frequent intervals from the time they were four inches high until they formed ears. In no case was even a trace of prussic acid found. The test for this poison is very delicate—so delicate that a single sorghum plant four inches high gives a very distinct reaction; yet even where a pound of the green stocks of maize was distilled and tested there was no indication of the presence of the acid.

A quantitative study of the prussic acid in sorghum was carried on at the same time as the above, and Bruennich's findings on sorghum were confirmed. As an illustration of this, the results of the analysis of three samples of sorghum from the same field are given below. Part of this field had been heavily manured and part had received no manure. All of the sorghum plants were of volunteer growth among alfalfa.

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*Journal of the Chemical Society (London) 1903, Transactions, p. 788.

Lot	Color	Average length of stalks.	Per cent of prussic acid.
1	Dark green	50 cm	0.01215
2	Yellowish green	35 cm	0.00499
3	Yellow	22 cm	0.00405

In February,1907, a field of cornstalks near Broken Bow in which several cattle had just died was visited by one of the authors in company with Dr. Peters, and all the suckers collected from the stalks on one acre. Part of these were fed to some calves and the rest were subjected to a thoro test for prussic acid, the test being made at Broken Bow as soon as the suckers were brought in from the field, so that there might be no possibility of its being lost between the time the plants were gathered and the time the test was made. No trace of prussic acid was found. The calves which were fed as many of the suckers as they would eat and were allowed no other food for twenty-four hours showed no ill effects.

ABORTION IN CATTLE

BY A. T. PETERS

This disease is by no means new. It has been reported for many years and the theories regarding it are numerous. Some of the best pathologists have busied themselves with the investigation of this disease. From time to time commissions have been appointed by agricultural societies of the different countries to study the breeding of live stock, and the infectiousness, cause, and cure of this disease. Very little can be learned from the early writers. In fact, the early literature on this subject has a tendency towards superstition, in that it invariably attributes the cause of epidemic abortion to sympathy, by saying that the animal is endowed with the instinct to know when another animal is so affected and that the odor or some mysterious omen would cause the animals to abort. The next theory was that abortion was caused thru bad feed, especially moldy grain. Investigation has shown that this is possible only in very rare instances. It was not until about 1885 that Nocard, who had then undertaken the investigation of this disease, clearly pointed to the contagiousness of this affection. He was the first to study carefully the exudate from affected animals in order to discover, if possible, the true and exciting cause. From that time the cause of this disease was attributed to the discharge of aborting cows, this discharge being carried on the straw and litter to the other animals, and this to a certain extent is true.

It was in 1897 that Bang verified the idea that this disease is contagious and demonstrated how the bacillus could be cultivated on artificial media and described the organism in detail. It was also thru Bang's investigations that the real cause of this disease was discovered and the fact determined that a large portion of this was due to the male. Heretofore the experiments had been exclusively made on the female by using strong disinfectants both internally and externally, thereby hoping to eradicate the disease, but it was found that by the most painstaking aseptic methods abortion could not be prevented. Prof. Bang called attention to the male and now by a combination of disinfecting the male and the female good results are obtained.

ACCIDENTAL ABORTION.— In dealing with abortion it should be first ascertained if it is of a noncontagious character. Noncontagious or accidental abortion may be due to a number of different causes; such as fright, spoiled food, violent purgation, injuries, thru bad treatment by an ill-tempered attendant, slipping on the ice, etc. One may enumerate a number of things that may cause this trouble but suffice it to say that when one cow aborts the owner should be very careful to look into the details and to ascertain whether it occurred thru an accident or whether it is contagious abortion. It is far better to be cautious and advise the owner to use the necessary precautions which are prescribed under contagious abortion. It is better to start the treatment early than too late. It has been the writer's experience that it is best to take this precaution.

CONTAGIOUS ABORTION.—If a considerable number of cows in a herd have aborted within a certain season or if the same cows have aborted in two or more successive seasons, if the disease has the tendency to spread to the other cows and especially if there is a history that the neighboring herds are affected with contagious abortion, then there is little doubt but that one is dealing with a case of contagious abortion. It is important to know whether any new stock has been added to the herd, for in a large per cent of cases the herds have been affected thru this channel. Proof was not always conclusive that the cow that aborted came from an affected herd, but it is true that cows brought into a herd very often abort, even when there has not been a case of abortion in the herd from which it came. This is not a case of contagious abortion but it can so affect a herd if drastic measures are not pursued. This is one of the sources of infection that should be carefully guarded against.

SYMPTOMS.—The symptoms of this disease are not plainly visthat it has a very slight elevation on which there is a peculiar eruption. This eruption may escape the eye that is not thoroly trained, as it is not very prominent. From aborting cows there is usually a slimy, flocky discharge. The cow may be restless for three or four hours before the expulsion of the young. In some instances the cow shows symptoms for a day or two by the udder filling up and the lips of the vulva thickening, showing the signs of natural gestation. This is accompanied by nervous excitement. Where cows carry their foetus for five to seven months the usual symtoms are the swollen condition of the vulva and later on entire laxation. In addition to these symptoms there may be a free flowing of exudate and as the symptoms increase this becomes more copious and may be streaked with blood. When these symptoms appear the expulsion of the young is near at hand.

THE CAUSE.—There is no question that the disease is caused by a germ, which has been described by Nocard and Bang. This germ cannot be killed very readily and on account of its being found in the discharge from the vagina and also on the male animal it is important that the stalls and floors be thoroly disinfected and that the bedding which may have been contaminated be burned, and also the foetus. Cows affected should be isolated and should have one attendant who does not take care of or come in contact with the healthy cows. It is important that one person be assigned to the infected herd and that he use the necessary precautions and that he do not walk into the stables where healthy cows are kept. Before he leaves the infected herd he should thoroly disinfect himself and leave the infected garments in a suitable place so that they can do no harm. If a cow aborts in the main stable she should be immediately removed and the premises should be as carefully disinfected as possible, using strong lye solution with plenty of hot water and a five per cent solution of carbolic acid. The most painstaking disinfection should be at once commenced. The animal in the quarantine pen should be treated immediately as follows: If the afterbirth has not come away within five to eight hours it should be taken away by one who knows how to perform this operation. The animal should then be irrigated with a two per cent solution of permanganate of potash, and the limbs, tail, etc., should be washed with soap and water and then with this permanganate of potash solution. One capsule containing oil and kreso is then placed into the vagina. This capsule on dissolving disinfects the vagina and the vagina should be irrigated every other day with this permanganate of potash solution and a capsule inserted. In addition to this the cow should be fed carbolic acid in the feed. The carbolic acid should be prepared as follows: Crude carbolic acid is liquefied and a small amount of glycerin is added to this to keep it in a liquid form. You start in by mixing with the bran two drams of this solution and then gradually increase the dose until it amounts to about six drams per day. The dose is increased according to the virulence of the disease. Best results have been obtained by giving large doses to cattle where the per cent of loss was very great. We have had the best of success with this treatment. Eighty-one out of 211 herds treated reported good results.

The bull is probably the carrier of the infection, and therefore the bull should be thoroly disinfected before and after each service. Use some antiseptic solution, as a tablespoonful of permanganate of potash to a pailful of water. A rubber tube can be used large enough to slip into the sheath of the bull, a funnel is fitted to the other end of the tube, and when this funnel is elevated it will force the solution well into the sheath and with the right hand the operator can work the solution thoroly to all parts of the sheath. The limbs of the bull should also be sponged with a good antiseptic solution.

STERILITY.—Sterility is one of the sequels of contagious abortion. The reason for this is that the microbes enter the Fallopian tubes and affect and eventually destroy the ovaries and therefore conception cannot occur. Many treatments have been used for this affection and there are a great many patent medicines on the market to be used for this disease but our investigations have shown that medicinal treatment has little or no effect. Out of 209 animals that were apparently sterile, 86 remained sterile in the herd for a year or more, 41 for eighteen months or more, while conception occurred in 11 which successfully gave birth to a calf. Post-mortems were held on 74 of these animals and all were found to have diseased ovaries, 42 out of the 74 having one ovary affected while 32 had both ovaries affected. It is interesting to know that the owners of these animals used the following remedies: dilatation of the *os uteri,* irrigating with sterilized alkaline water, using yeast treatment, and the various patent medicines offered for the cure of this disease. We lost trace of 135 of these animals, but our investigation shows that remedies are of little avail since 100 per cent of those on which we held post-mortems had diseased ovaries. This should discourage the owner from keeping cows that will not conceive, especially if the animal has aborted. The animals should be fattened as soon as possible and sold on the market.

CONCLUSIONS.—Abortion in cattle is caused by a germ which is found in the exudate of the female and of the bull. Therefore both cows and bulls should be thoroly disinfected before and after breeding. Newly purchased cows should be kept in quarantine and should be washed with an antiseptic solution. A cow that has aborted should be immediately placed in quarantine and an attendant should take care of these animals and avoid coming in contact with healthy animals. The bull should be disinfected before and immediately after each service. Cows should not be allowed to calve in the presence of other animals.

TUBERCULOSIS

By A. T. Peters *

During the winter of 1907, when the legislature was in session, a resolution was passed requiring the Department of Animal Pathology to investigate tuberculosis among swine in our State. An appropriation of $1,000 was made to carry out the provisions of the resolution. Prior to this time there had been nothing done on account of lack of funds. Our State Veterinary Department has only a meager appropriation, which barely covers the expenses of police work. For this reason it could not take up in detail the work of tuberculosis.

After the appropriation became available, our department immediately began to study the question of tuberculosis. We made arrangements with the Bureau of Animal Industry whereby we secured the names of owners who had shipped live stock to the South Omaha market and who had part of their animals condemned for tuberculosis. We afterwards tried to visit their farms to ascertain the conditions existing on these farms. It was important for us to become familiar with the kind of live stock these farmers owned, the number of cattle and hogs on the place, the way they were fed, and whether, previous to our visit, they had any knowledge of their stock having tuberculosis. The Government reported 281 farms as sending tuberculous stock. These 281 farms were located in fifty-five counties. Of these fifty-five counties, forty-seven were for swine tuberculosis and forty-one for tuberculosis in cattle. In thirty-three of these counties tuberculosis was reported in both cattle and hogs.

from these counties, the percentage of condemnations is very large, running sometimes more than 3 per cent. When the percentage of condemnations for any given day has been very large, an examination of the records showed that the counties known to be greatly affected with tuberculosis in swine had supplied the greater percentage of that day's killing. This was tested repeatedly when we would receive information from the Government Inspector that the condemnations were unusually numerous. This proves the assertion made by Dr. Burton Rogers several years ago, when he undertook to tag 3430 hogs before the farmers unloaded them from their wagons. These tagged hogs were always killed separately. In this way he was able to trace back to the owner every tuberculous hog. He states that out of about 600 different hog-raisers bringing hogs to this one market, thirty-nine brought in all the tuberculous hogs. Our work in Nebraska in cooperation with the Government in trying to trace the source of tuberculous animals is giving evidence that Dr. Rogers's statement is true that infection comes from a small area, and that if the State was so provided with funds and facilities and a definite knowledge of where the infection existed that it could purchase and slaughter these animals, and thereby clean up infected areas, it would materially aid in stamping out tuberculosis in a short time. I wish to mention here that not only is it necessary for the State officers to be provided with ample funds to carry on this work, but I find that it is also necessary to have the people well educated in the fundamental principles of tuberculosis, and the owners of live stock thoroly conversant with the dangers of this disease. They should know how the disease spreads, how to prevent it, and that it is an economical proposition to them to study the importance of tuberculosis. Tuberculosis among hogs is far more treacherous than hog cholera, which only visits the farms once in many years, as proved by statistics, while tuberculosis remains on the premises permanently if the owner does not do anything to eradicate this disease, and will eventually drive him out of business. For this reason it is important that the methods in our State work should be thoroly revised, so that not only large appropriations shall be granted, but provisions shall be made to thoroly educate the farmers and stockmen as to the dangers of this disease. This education should be one that would not scare or frighten the owner so that he would feel that the literature he was receiving was an exaggeration, thereby making him an enemy to tuberculosis legislation instead of promoting the cause. I have been watching the progress that is being made in other States regarding this important subject, and the more I have studied the question the more I have become convinced that when the stockman is thoroly familiarized with the issue and given plenty of time to think over the question, he is a very good man to work with, and would favor reasonable legislation. Knowing this fact, I started the work in our State by organizing a reading club. This reading club is largely composed of farmers and stockmen thruout the State. Ninety per cent of the members make stock-raising their principal occupation. These men were interested in the reading club, and the only requirement made was that after a certain period they must return question blanks, properly filled out, before they could secure new literature. Lack of funds prevented us from printing literature, but the Government and the experiment stations, having a large number of pamphlets that are well adapted for this work, were applied to and sufficient copies secured. These were then gone over and questions prepared. These questions were sent to the members of the club, who filled out and returned the reply blanks to the office. After the blanks had been returned, another pamphlet was sent to them. Not only have we used the members just for the reading club, but we have secured a number of them to do missionary work in their own locality and secure new members. Many of the members have urged stockmen and dairymen in their community to have their herds tested for tuberculosis by our Department or by the local veterinarian. In this way much good has been accomplished. We also feel that thru this reading club we are securing a large number of people who will be willing to give accurate information to our various stock associations and to the members of our legislature if it becomes necessary to pass a suitable law for the eradication of tuberculosis from the State. Largely thru the reading club and thru cooperation of the Bureau of Animal Industry we have been able to test 63 herds of cattle, with a total number of 3602 head. Three and sixty-eight hundredths per cent of these cattle reacted to the tuberculin test.

Out of 281 farms reported to us, 222 were visited by representatives of our department and the conditions carefully studied. We found that on many of the farms where tuberculosis existed among the hogs they were receiving separator milk. We noticed, however, that a larger percentage than had been expected had never received dairy products, and that skim milk was by no means entirely accountable for the infection of tuberculosis in hogs. Two herds in particular where there was a large condemnation had not been receiving dairy products. It was discovered later thru the tuberculin test and the post-mortem examinations that tuberculosis existed among the cattle. Previous to destroying these animals, samples of the fecal matter were secured, and examinations of the same revealed tubercle bacilli. The method given in Bulletin No. 99 of the Bureau of Animal Industry, United States Department of Agriculture, was used for making these examinations.

I have become more and more a believer that hogs become affected to a large extent through fecal matter, because of the habit of breeders of allowing their hogs to follow cattle. There is no question but that this practice gives occasion for a large percentage of the condemnations among the hogs. Thru this matter the lymphatic system becomes infected, and glandular tuberculosis, which is by far the most frequent, is caused by hogs being compelled to follow and gain their sustenance thru the offal of diseased cattle. We are making careful examinations along this line to verify more conclusively this statement. But enough evidence is at hand at this time to warrant the assertion that if our system of feeding hogs were changed the number of tuberculous hogs would be greatly reduced. There is no question but that we have overlooked the great source of infection, that is the fecal matter, and on account of this oversight the States that are supplying a large percentage of the hogs have suffered such a rapid increase in the disease. The conclusions of our laboratory work are as follows:

1. Tubercle bacilli may pass thru the intestinal tract of cattle and retain their virulence.

2. Tubercle bacilli in the feces of cattle may readily contaminate dairy products and cause infection in hogs.

3. Animal inoculation and a microscopical examination of the lesions produced are necessary to definitely establish the presence of tubercle bacilli in cow feces.

4. Ingestion experiments with hogs, previously proven to be free from the disease by application of the tuberculin test, are valuable means of demonstrating tubercle bacilli in the manure of cattle.

5. Hogs should not be permitted to run in the same pens with cattle, especially if the latter are known to be tuberculous.

6. Consuming milk from tuberculous cows, even tho there is no infection of the udder, is a source of danger to man.

7. The number of tuberculous cows which show no symtoms of disease but which excrete virulent tubercle bacilli in their manure is sufficiently large to make this an important factor in the control of tuberculosis.

Cooperation at the packing centers between the Government and the State is practical, fruitful of results, and important, and should be cultivated and perfected. The Government is in a position to aid the State authorities in a most effective way if the State authorities are only willing to accept the assistance. It is thru the Government Inspectors that the State can locate the infected centers; and then if these places are visited by representatives and the conditions noted, the representatives can in the larger percentage of cases persuade the owners to clean up their herds. It is a pleasure to me to report that 66 of the 281 farms reported to us have cleaned up their herds in one way or the other, either by using the tuberculin test or by sending the animals to the abattoirs subject to inspection; and that these people are assisting the department at this time. They are very desirous of not having diseased stock on their premises. It is a remarkable fact that 92 per cent of the 281 farmers reported that previous to our visit they had no knowledge of any disease in their herd, and were very much surprised when they were informed that animals had been destroyed. This is all the more emphasized where hogs had been condemned by the inspectors of the Government itself. One of the embarrassing features that we had to contend with in visiting these farms was to inform the owner that the Government had condemned animals of his shipment, for it is a fact that repeatedly some of the best-looking animals, and the ones that topped the markets at the abattoirs, have been condemned. It has been a surprise to the owner when we would visit him a week later and tell him that four, five or six of his animals had been condemned, and it is a very difficult matter to explain to the stockman how fat animals in a prime condition and topping the market could be condemned by the Government Inspectors. And then comes the task of convincing this man that the Government official really did find the disease in the carcass, and that it would be well for him to clean up the remainder of the herd. Here again comes in the value of resorting to literature and correspondence. I will admit that we could not at the first time convince an owner that the remainder of his herd was in danger, but by supplying him with literature we convinced him that it is possible for animals in the best condition to be diseased. These men have become thoroly interested and are working for better conditions. In going over the map of our State which shows the affected areas I must again call attention to the fact that has been observed by Dr. Rogers, that the infection is located in but few districts, and to secure this information I believe that it would be well for our Government to make regulations by which the animals could be identified when they reached the killing floors. Much as I have investigated this matter and spoken with the proper authorities about a tagging and identification system of this kind, they have not thought it feasible. I am sure that the time will come when such tagging will be necessary, for if the Government or the States will continue to follow the source of infection and find the same, as we have done in our State, it will show that tagging is the only feasible way of eradicating this disease, and that it is much cheaper than any other method. At the present time it does not seem popular, but I believe that by proper agitation, bringing the matter before the public, the opposition would soon be greatly diminished.

The work that is in progress at this time is a continued study of the source of infection and the promotion of our reading club thruout the entire State, so that the people will make requests to have their herds tested instead of being compelled by law to have it done. From now on this work will be conducted by the State Veterinary Department. The importance of this campaign of education is shown by the fact that if we had assistance enough we could test practically as many herds in one month as we tested in the twelve months last year. It is hoped that aid will be given to the State authorities to meet these demands by the creation of sanitary boards similar to the ones existing in Pennsylvania and Minnesota. From our reports and from the statistics at hand it seems as tho the infection has not gained any considerable foothold in the State of Nebraska, and that if suitable measures were to be enacted at an early date, the disease could be prevented from spreading and eventually stamped out.

The Bang system has been advocated in our State, and also a modification of this system made by Dr. Johnson, but neither of these has been found to be practical on our farms, for it seems to be very expensive to maintain this system. Several of the best breeders in our State have been investigating the question, and no doubt experiments along this line will be taken up.

Vaccination against this disease has not been recommended, on account of lack of funds; and, furthermore, as our department has considered it still in its experimental stage, we for this reason did not care to use this treatment, as it may prove a hindrance to the eradication of tuberculosis. The department is watching with great interest the experiments conducted by others along these lines.

The tuberculin test has proved very satisfactory, and thru this agency we have a means for detecting tuberculosis in a herd, and we can very readily clean up a herd. This work encountered a great deal of opposition, for the reason that the State had no compensation to offer for these cattle. It is interesting to know hearty cooperation instead of their antagonism, and by the splendid aid of the agricultural press, progress in stamping out tuberculosis will be achieved.

The following is a list of bulletins of the Bureau of Animal Industry and the Experiment Stations that have been secured for the reading club in our State:

Circular 118 of the Bureau of Animal Industry, United States Department of Agriculture: "The Unsuspected but Dangerously Tuberculous Cow."

Bulletin 92 of the Iowa Experiment Station, Ames, Iowa: "Tuberculosis in Swine."

Bulletin 277 of the New York Experiment Station, Geneva, N. Y.: "The Bang Method of Controlling Tuberculosis, with an Illustration of its Application."

Bulletin 44 of the Bureau of Animal Industry, United States Department of Agriculture: "Infectiveness of Milk of Cows which have Reacted to the Tuberculin Test."

Bulletin 38 of the Bureau of Animal Industry, United States Department of Agriculture: "Tuberculosis of the Food-producing Animals."

Paper by Dr. G. A. Johnson, of Sioux City, Iowa: "The Disposition of Tuberculous Cattle."

Circular 79 of the Bureau of Animal Industry, United States Department of Agriculture: "The Tuberculin Test for Tuberculosis."

Bulletin 78 of the New Hampshire Experiment Station, Durham, N. H.: "Bovine Tuberculosis."

Bulletin 77 of the North Dakota Experiment Station, Agricultural College, N. D.: "Bovine Tuberculosis in Herds."

Bulletin 126 of the Wisconsin Experiment Station, Madison, Wis.: "Two Ways of Treating Tuberculosis in Herds."

Circular 70 of the Bureau of Animal Industry, United States Department of Agriculture: "Tuberculosis of Cattle."

Bulletin 108 of the Ohio Experiment Station, Wooster, Ohio.: "Bovine Tuberculosis."

Sample of the questions prepared on a bulletin which was sent to the members of the Tuberculosis Reading Club and the answers to the same.

1. What is the cause of tuberculosis?—Lack of sunlight, too much stabling, poor ventilation, feeding milk from tuberculous animals, and coming in contact with tuberculous animals. The direct cause of this disease is the growth within the animal tissues of a vegetable organism known as the tubercle bacillus.

2. Is tuberculosis hereditary?—Tuberculosis is not hereditary but the tendency of making the individual more liable to tubercular infection may be inherited.

3. What is tuberculin?—Tuberculin is a liquid obtained by heating tubercular material until the germs are killed and then straining the same to remove their dead tissues.

4. Is tuberculin a cure for tuberculosis?—Tuberculin is not a cure for tuberculosis, but it has proved to be the best thing to indicate the presence of the disease.

5. Can people take or get tuberculosis from meat or milk of tuberculous animals?—People can take tuberculosis thru milk from tuberculous animals if it is not sterilized and thru the meat of tuberculous animals if it is not thoroly cooked.

6. Is tuberculosis contagious like measles or smallpox?—No. It is a germ disease and can be caught from the sputum or feces of infected animals and also from the sputum of the human family. Sometimes the whole herd becomes infected from a single animal or thru the carelessness of an attendant.

7. How is the tuberculin used in testing for tuberculosis?—Four temperatures are taken two hours apart, then the tuberculin is injected, and within eight to ten hours after the injection four temperatures are again taken two hours apart. If there is a rise of two or more degrees in temperature after the injection then the animal is said to react.

8. If a cow has tuberculosis, how can you tell it by using tuberculin?—A rise in temperature of two or more degrees within eight

9. Does tuberculin always cause reaction when an animal has tuberculosis?—It does not cause reaction in animals that are in the last stages of the disease.

10. Why do you think that there should be more cases of tuberculosis in hogs than in cattle?—As a rule hogs are confined in darker and damp quarters and they are more susceptible to disease. They get it from following tuberculous cows and from drinking the milk of tuberculous cows, as the germ passes off in the manure and also to some extent in the milk.

11. Why should cattle kept in close, dark barns be more liable to have tuberculosis than when kept in light, airy barns or on pastures?—Because the conditions for the bacteria to multiply are not very favorable in light, airy barns or on pastures. The germs will thrive in darkness and foulness but when they come in contact with the sun and fresh air they are destroyed. Poor ventilation soon affects the lungs, putting the whole system in poor shape for resisting the disease.

12. Are you able from external appearance to tell whether or not an animal has tuberculosis?—No, not until it is in a very advanced state and not always then.

13. Will tuberculin produce tuberculosis?—No. Why?—Because tuberculin is obtained only from dead bacteria of tuberculosis; that is, the germ is killed during the process of making the tuberculin.

14. Is meat from a tuberculous animal always dangerous?—No. Why?—It is only dangerous when some of the body glands are affected, but when some of the minor glands are affected the whole body need not be condemned. The disease may be only specialized and not generalized.

15. After an animal is killed how can you tell whether it had tuberculosis?—One can tell by the grayish white granules the size of millet seed usually found on the liver or digestive organs and on the lungs or glands of the neck. If the animal is badly affected the insides of the ribs, where the lungs are located, are full of white grayish granules.

16. Do calves inherit tuberculosis from their parents?—Calves

do not inherit tuberculosis from their parents but may get it thru drinking the milk and by coming in close contact with the parent. They inherit a tubercular tendency.

17. Why is it necessary to take the temperature of an animal before injecting tuberculin?—To determine whether the temperature is normal. When an animal is driven or excited or in periods of sexual heat the temperature affects the accuracy of the test.

PRODUCTION OF A NEW FORM IN WHEAT

By E. G. Montgomery

The accompanying chart gives some interesting historical data regarding the occurrence of what appears to be a new type of wheat. At least it seems new so far as the ancestry of either parent can be traced.

In 1903 a number of crosses were made of Turkey Red, a bearded wheat, by Big Frame, a smooth wheat. Records were kept by Professor Keyser on a number of these crosses for three generations, in a study of Mendelian characters. The only characters which could be followed with accuracy were the bearded or beardless type of spike and in this the crosses followed Mendel's law,[1] the hybrids being distinguished as an intermediate type. From the first generation, grown in 1904, three intermediates were selected for planting, 100 seeds being planted from each. From the second generation in 1905, five bearded (b), five intermediate (i), and five awnless (a) plants were selected from each. Notes were taken on all progeny in 1906, and the study of Mendelian characters was then dropped, but a few selections were made and continued, to test their possible value as new stocks of wheat.

In 1906 and previous to that, no unusual form had been noted, but in 1907 one centgener, No. 111, was markedly different from the others. The straw was about 6 to 10 inches shorter and the wheat ripened fully one week earlier than the other plats. All the plants in the centgener of 100 plants appeared to be of this type. None of these plants were noted in other centgeners. (For convenience we will hereafter refer to this as new type A.)

In the fall of 1907 three plants from this centgener of new type plants were planted each to a separate centgener, and these all came true to the new type in 1908. Other centgeners from plants of the pure bearded or pure awnless type were also planted.

All the 1908 plats came true as expected, but in four other centgeners, all from 1907, Plat 108, a few plants of the new type occurred, 2 or 3 plants to each centgener. Also 5 centgeners were planted from 5 selected plants from 1907, Centgener No. 113. All these came true to the regular bearded type except that in one, No. 35, a few plants of a new type occurred, similar to the other mentioned above except a little taller and later in maturing. (Hereafter referred to as new type B.)

In 1908 we could divide for convenience the new types into 3 groups: first, the three plats 32 to 34, from 1907 Plat No. 111,—all of this type A; second, the few new type plants exactly like them occurring for the first time in Centgeners 27 to 31; and third, a few plants of a similar new type but larger and later in maturing, in Plat No. 35.

A few plants were selected from each of the three classes and planted, each plant to a centgener, in the fall of 1908. In every case they came true in 1909, except that a few reversions, less than one per cent, of both the original bearded and the beardless type occurred. Also normal plants were selected from each centgener in which the new type occurred, as well as normal plants from centgeners that had not borne such new type. In most of the centgeners from normal plants that had sister plants of the new type, as Centgener 68, a few type A plants again occurred altho most of the plants would be normal.

Also the plants of new type B from 1908, Centgener 35, came true but, as in 1908, they differed from the other new type in being larger and later.

A most interesting occurrence, however, was the appearance of a few plants of type A in 1909, Centgener No. 43 to 46, this being the sixth generation from the cross and the first time in this direct line that the new type had occurred.

The number of plants grown from each type and the amount of variation from type is shown by the following table, which gives the data for 1909.

Type	No. of centgener plants	Approximate total number of plants at harvest	No. of normal bearded plants	No. of normal awnless plants	No. type A plants	No. type B plants
Normal bearded plants from plats having few type A in 1908.	25	1650	1600	....	51	......
Type A plants selected in 1908.....	31	2170	14	9	2147	....
Type B plants selected in 1908.....	5	350	2	1	....	347
Plats 43 to 46, composite samples of sister plats to 35 in 1908. All normal plants.......	4	280	262	....	....	18

This table shows that when normal plants were selected from plats where a few new type occurred for the first time (Nos. 27 to 32, see chart) out of 1650 plants produced, 51, or about 3 per cent, were of the new type.

From 31 selected plants of new type A about 2170 plants were produced, all coming true except 23 reversions to both the original parent types. An interesting point in regard to these reversions is the case of the 9 smooth plants of the parent type, since all these selections had been from pure bearded parents, and none of the smooth type had ever appeared.

Five selected new type B plants produced about 350 plants and 3 reversions.

Four composite samples were taken in 1908 from 4 plats, sister plats to 35, the one which produced type B. These which did not show any of this type in 1908 produced in 1909 about 280 plants, 18 of which were type B (see chart). This was the sixth generation from the cross.

It seems that the new type A must have been in some way the result of crossing Turkey Red and Big Frame wheat. Also this type remained latent four, five and six generations before appearing as a new form. Then when planted it came true to type as a mutant is supposed to do. This suggests the possibility of a new type, resulting from a cross, lying dormant for many generations and then appearing in numbers as an apparently new form.

Another interesting feature was the occurrence of sterile spikes among the new type plants. The heads were much longer than ordinarily while the spikelets usually developed 4 to 5 flowers, the ordinary being 2 to 3 flowers. The sterile flowers had well developed ovaries but the anthers were undersized. DeVries also mentions the occurrence of sterile flowers in one of the "mutants" of *Oenothera Lamarckiana.* In fact the whole behavior of this wheat is very similar to the case of mutation DeVries reports in *O. Lamarckiana,* especially in the constant recurrence of the new type in selected strains of the original, and in the reversions to original type which occur in pure selections of the new type. This all suggests the possibility of a cross sometimes causing the production of mutants. The fact that all other wheat crosses we have made have followed Mendel's laws so far as observations have been made, and only this one has given the new type, suggests that now and then a cross may act in an unusual way.

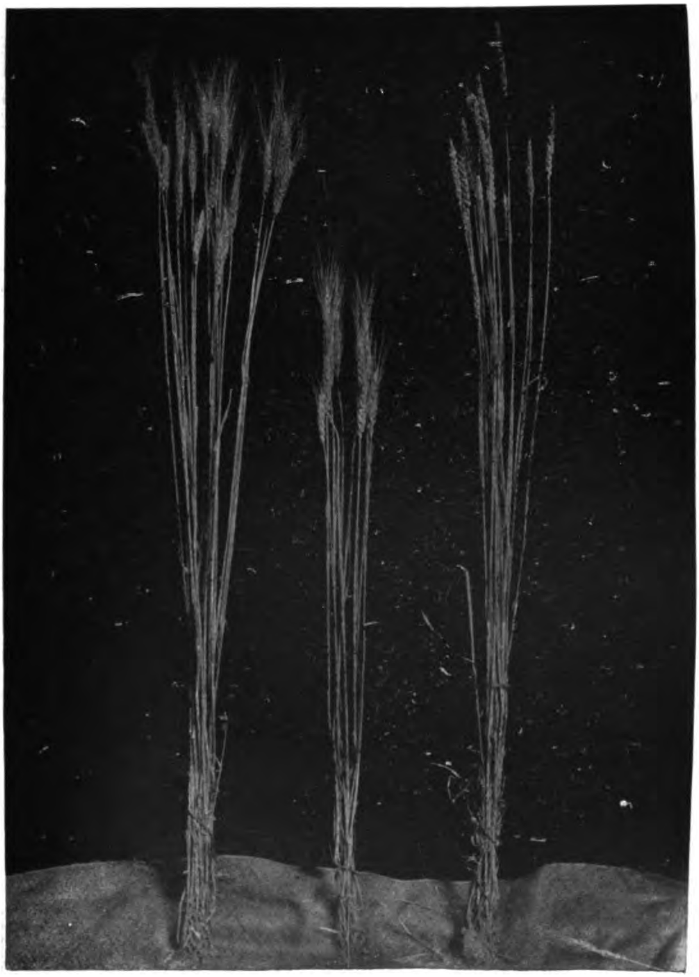


Fig. 1. The new type and two parents. 1, Turkey Red; 2, Big Frame; 3, the new type A.

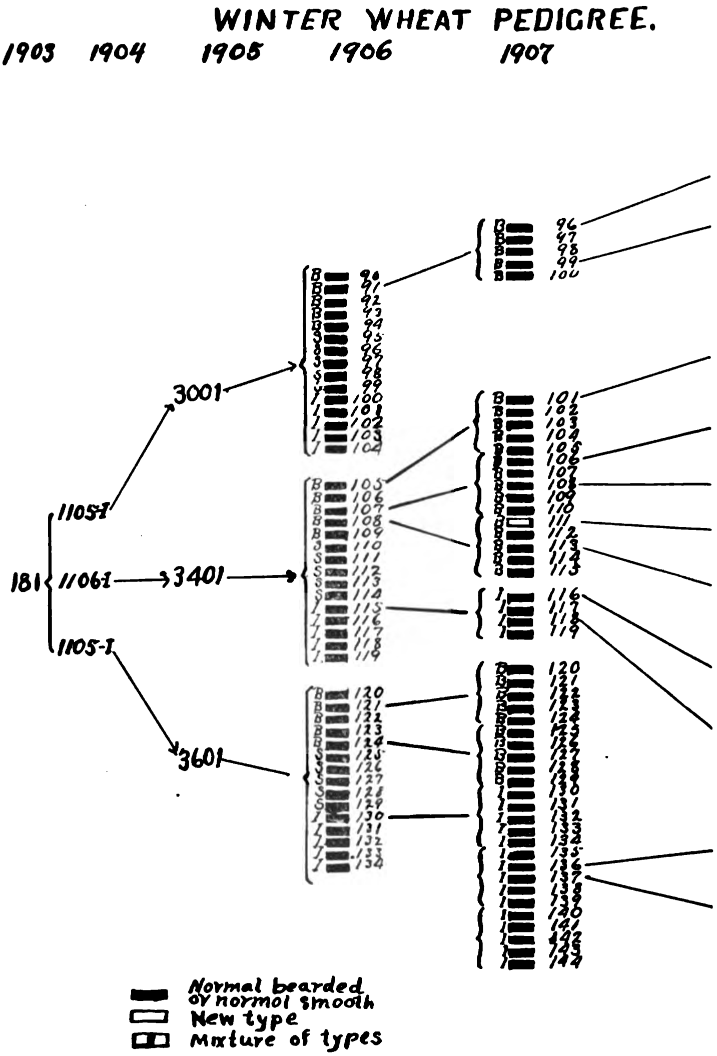
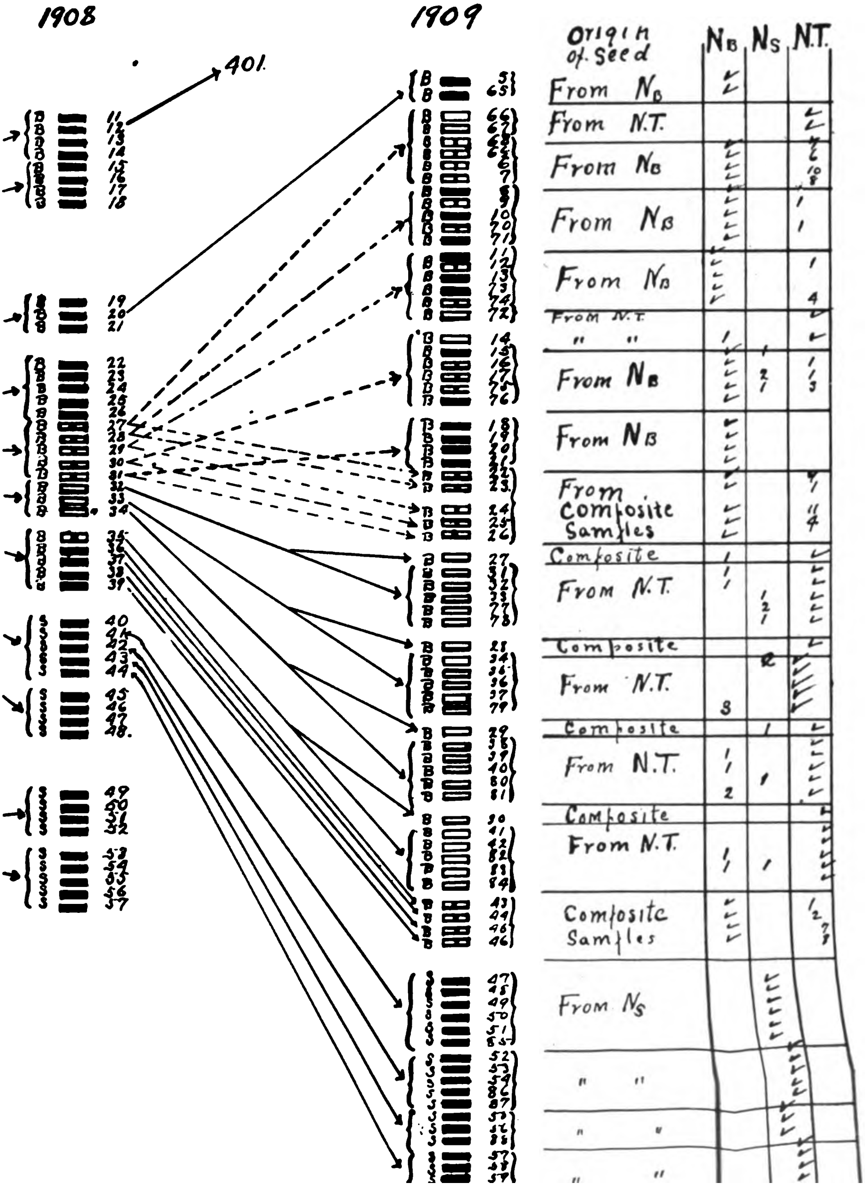


Chart showing pedigree record of wheat family No.

TURKEY RED × BIG FRAME. 6 GENERATIONS



SOIL MOISTURE STUDIES AT THE NORTH PLATTE SUBSTATION*

By W. W. Burr.

In the spring of 1907, studies were commenced to determine the most practical method of storing water in the soil and the methods of cropping which would utilize to the best advantage the soil moisture.

GENERAL CONDITIONS.

Part of the land used in making these studies is bench or second bottom land, and part is table-land. The soil on the table-land is very similar to that on the bench. On the bench land, sheet water is only 35 to 40 feet below the surface. It may be that subirrigation takes place with deep-rooted plants like alfalfa. On the table-land the sheet water is from 200 to 250 feet below the surface and crops can not get water by subirrigation. This absolute dependence of the crop on surface precipitation gives the best conditions for the study of soil moisture.

TYPE OF SOIL.

Before taking up the discussion of the sampling it may be well to consider the type of soil that is found on the Station farm, as it is very important that one bear in mind the character of the soil on which one is working. Different results will necessarily be obtained as the character of the soil varies. The soil of the Station farm is what is known as "hard" or "short grass" land, this term being used to distinguish this type of soil from the sandier soils. It is called "loess" soil and would be classified as the silt loam. On the more level portions of the farm the native vegetation was mainly buffalo and grama grasses, while on the broken portions of the farm the vegetation is mainly bunch grass. The soil is quite uniform to a considerable depth, the most noticeable change being less organic matter in the subsoil, indicated by the change in the color of the soil. This change in color usually begins within three or four feet of the surface.

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*The data presented in this article are the result of work done

The following table gives the results of eight mechanical analyses made of the upland soils:

TABLE I.—*The mechanical composition of the upland soil at North Platte, Nebr.*

ANALYSES MADE BY THE BUREAU OF SOILS, U. S. DEPARTMENT OF AGRICULTURE.

Depth of sample	Organic matter	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	2.1	0	.1	Tr.	1.5	52.5	36.1	10.5
2	1.0	Tr.	0	.0	1.4	50.8	36.1	11.9
3	.8	0	.1	.1	9.2	43.2	34.0	13.3
1	1.7	0	.3	.1	4.3	48.9	38.6	7.3
2	.3	0	.2	.1	2.7	55.4	32.5	9.1
3	.2	0	.0	.1	1.6	58.2	30.4	10.0
1	.9	0	.3	.1	2.1	51.0	36.1	10.3
2	.9	0	.1	.2	12.3	37.8	40.6	8.6
3	.4	0	.1	Tr.	3.6	42.9	42.3	10.5
1	.7	0	.1	.1	5.8	43.8	43.2	6.3
2	.5	0	.1	.1	5.0	44.7	42.0	7.5
3	1.0	0	1	.1	8.2	42.7	39.2	8.9
1	2.4	0	.2	.2	6.9	43.1	42.8	5.8
2	.5	0	.1	.1	6.0	43.4	42.7	6.7
3	.6	0	Tr.	.0	4.4	40.7	45.8	8.1
1	.5	0	.7	.3	10.1	43.5	35.8	9.3
2	.8	0	.2	.3	8.3	42.6	37.1	11.2
3	.7	0	.1	.1	5.6	44.0	36.6	13.3
1	1.0	0	.2	.2	3.6	42.8	43.6	9.2
2	.9	0	.1	.1	6.0	46.3	36.4	10.8
3	.8	0	.1	.1	4.1	46.9	35.3	13.1
1	1.0	0	.4	.2	14.1	38.7	38.4	7.5
2	.8	0	.4	.2	6.6	45.5	36.1	10.8
3	.2	0	.1	.1	4.0	49.6	31.2	14.5

From Table 1 we note that the soil has a low per cent of all material coarser than a very fine sand. This with a low per cent of organic matter would indicate that the soil would bake or crust badly. There is, however, a correspondingly low per cent of clay and the soil is easily tilled. No trouble has been experienced as yet with the soil baking or running together badly. We do, however, find that under the drying winds of spring before tillage commences the soil cracks open.

MANNER OF SAMPLING.

The soil samples are taken with a tube sampler. The cutting edge of the tube is about three thirty-seconds of an inch smaller than the inner diameter of the tube. The tube is marked in foot sections. After a core of soil is taken the tube is simply inverted and the sample slips out. This method of sampling allows very little chance for the mixing of the various foot sections. After taking the sample it is put in an air-tight box, taken to the laboratory, and weighed, to get the moist weight of the soil. It is then heated to 110° C until dry, and reweighed, the loss in weight being considered the weight of the water.

DEPTH OF SAMPLING.

During the season of 1907, most of the samples were taken to a depth of only three feet, but some to a depth of six feet. It was found that the moisture was affected below this depth, and beginning with 1908 most of the sampling was carried to at least six feet. During the latter part of the season of 1908 a ten-foot tube was procured, and samples were taken to a depth of ten feet. This year (1909) we have sampled all of our fields to a depth of 15 feet, as we found that the moisture was affected even below 10 feet. The reason for such deep sampling is to find the point where the moisture content remains constant; that is, the point where the moisture is not affected by the tillage on the surface or by growing crops. We feel that it is necessary to do this deeper sampling in order to determine how far moisture may move up from below and supply water to the crop, and also to find out if the water that is below the reach of the plant this year may not be drawn upwards during the winter and be used by the crop the following year. We must have these determinations before we can ascertain how much water was used by the crop, for altho we know how much water has been used from the upper six feet of the soil we can not say that this represents all the water that was used unless we know that no water was used from below this depth.

A portion of the farming land is what is commonly known as bench or second bottom land. The remainder is table or upland. On the bench land, sheet water is from 35 to 40 feet below the surface, and on the table it is from 200 to 250 feet below the surface. The soil on the bench is very similar to that on the table.

EXPLANATION OF TABLES.

The column marked "depth" gives the depth in foot sections that the samples were taken. The date of sampling appears at the top or above each column. All moisture weights are figured on the basis of the dry weight of soil; for example, 10 per cent represents that for each hundred units of dry soil there were ten units of water present. The percentages given are the averages of all the samples taken at that depth and on that date in the field or plat. The averages shown are made by averaging three, six, or ten feet as the case may be.

HISTORY OF THE FIELDS.

The results given under the head barley, oats, wheat, and corn were obtained on the table-land under a system of cropping, which is being carried on in cooperation between the Office of Dry Land Agriculture of the U· S. Department of Agriculture and the Substation.

The field on which this work is carried on was broken out about 1887 and has been under cultivation since that date. In the spring of 1906 the plats were laid out as they are to-day. In each case Plat A was spring plowed and harrowed before planting. Plat B in small grain is disked after the binder, fall plowed, and usually disked and harrowed in the spring. In case the soil is rather loose in the spring the disking is omitted. Plat B in corn is fall plowed as soon as the corn is taken off. Plats C and D are given alternate cropping and summer tilling; that is, one season Plat C grows a crop while Plat D is being summer tilled. The following season D is cropped and C is summer tilled.

TABLE II.—*Soil moisture determinations, 1907.*

	Depth	April 6	April 22	May 6	May 21	June 6	August 2
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
A—	1	14.6	10.8	19.1	15.6	21.5	12.3
	2	16.1	11.5	15.2	15.7	17.4	9.4
	3	15.6	12.1	14.5	14.4	14.7	8.9
	4	....	....	....	....	....	9.4
	5	....	....	....	....	....	12.5
	6	....	....	....	....	....	12.5
Average to	3	15.4	11.5	16.3	15.2	17.9	10.2
Average to	6	....	....	....	....	....	10.8
B—	1	15.9	12.2	17.6	17.0	20.5	11.3
	2	16.9	12.6	16.2	16.4	18.9	8.7
	3	16.4	12.9	16.2	16.1	16.7	8.5
	4	....	....	....	....	....	9.6
	5	....	....	....	....	....	13.5
	6	....	....	....	....	....	14.6
Average to	3	16.4	12.6	16.7	16.5	18.7	9.5
Average to	6	....	....	....	....	....	11.0
C—	1	15.6	12.3	19.2	17.6	21.9	19.9
	2	16.6	12.7	16.5	17.1	20.0	18.2
	3	15.5	12.3	15.5	15.9	17.6	16.8
	4	....	....	....	....	....	15.9
	5	....	....	....	....	....	19.4
	6	....	....	....	....	....	17.0
Average to	3	15.9	12.4	17.1	16.9	19.8	18.3
Average to	6	....	....	....	....	....	17.9
D—	1	14.7	12.9	20.1	16.7	20.4	10.0
	2	14.2	12.7	16.4	16.5	17.5	8.6
	3	15.9	12.1	14.8	15.8	15 8	8.2
	4	....	....	....	....	....	8.8
	5	....	....	....	....	....	10.3
	6	....	....	....	....	....	13.7
Average to	3	14.9	12.6	17.1	16.3	17.9	9.6
Average to	6	....	....	....	....	....	9.9

TABLE III.—*Soil moisture determinations, 1908.*

	Depth	April 15	May 8	May 22	June 6	June 25	July 11	August 8	Sept. 18
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
A—	1	10.2	15.9	16.6	14.4	15.9	8.9	9.1	6.6
	2	8.3	8.7	11.7	12.9	11.1	7.7	9.1	8.2
	3	8.6	9.2	8.3	8.2	10.7	8.5	9.2	8.8
	4	......	9.3	......	8.5	......	8.2	9.4	8.3
	5	......	12.3	......	10.5	......	10.0	12.3	10.1
	6	......	12.9	......	11.4	......	10.7	13.3	11.1
	7	......	......	......	......	......	......	......	9.4
	8	......	......	......	......	......	......	......	9.1
	9	......	......	......	......	......	......	......	8.6
	10	......	......	......	......	......	......	......	8.3
Av. to	3	9.0	11.2	12.2	11.8	12.6	8.4	9.1	7.9
Av. to	6	......	11.4	......	22.0	......	9.0	10.4	8.8
B—	1	14.0	19.2	14.9	11.6	17.0	8.8	12.4	9.1
	2	12.7	12.8	16.3	12.9	11.6	7.9	8.8	9 0
	3	10.1	9.1	10.7	10.6	11.5	9.1	9.0	8.9
	4	......	9.4	......	9.0	......	9.4	9.8	11.3
	5	......	12.7	......	11.9	......	12.3	12.5	13.3
	6	......	13.2	......	12.8	......	12.9	13.5	12.7
	7	......	......	......	......	......	......	......	11.2
	8	......	......	......	......	......	......	......	10.3
	9	......	......	......	......	......	......	......	9.4
	10	......	......	......	......	......	......	......	8.9
Av. to	3	......	13.8	13.9	11.7	13.4	8.6	11.0	9.0
Av. to	6	......	12.2	......	13.4	......	10.1	11.0	10.7
C—	1	14.5	19.1	15.9	10.2	18.5	8.3	9.8	8.7
	2	15.3	16.1	17.2	12.4	12.3	8.6	9.0	9.0
	3	15.3	14.6	16.2	14.1	13.2	8.7	9 0	9.0
	4	......	14.2	......	14.5	......	9.3	9.4	9.6
	5	......	16.9	......	18.9	......	15.4	14 2	14.7
	6	......	16.3	......	17.2	......	14.9	14.8	14.2
	7	......	......	......	......	......	......	......	11.7
	8	......	......	......	......	......	......	......	10.9
	9	......	......	......	......	......	......	......	10.9
	10	......	......	......	......	......	......	......	10.7
Av. to	3	15.0	16.6	16.4	12.2	14.6	8.5	9.3	8.9
Av. to	6	......	16.2	......	14.5	......	10.9	11.0	10.9
D—	1	14 0	19.2	......	19.6	......	20.3	17.1	15.6
	2	13.6	12.2	......	18.5	......	18.0	17.3	16.3
	3	9.1	8.2	......	12.8	......	17.0	16.6	15.5
	4	......	9.1	......	10.3	......	15.4	15.9	15.3
	5	......	12.5	......	12.1	......	14.6	17 8	16.3
	6	......	12.4	......	12.3	......	13.1	17.5	15.3
	7	......	......	......	......	......	......	......	11.5
	8	......	......	......	......	......	......	......	9.7
	9	......	......	......	......	......	......	......	8.9
	10	......	......	......	......	......	......	......	8.8
Av. to	3	12.2	13.2	......	17.0	......	18.4	17.0	15.8
Av. to	6	......	12.3	......	14.3	......	16 4	17.0	15.9

TABLE IV.—*Soil moisture determinations, 1909.*

lowed. Oats every year.

March 30	April 12	May 6	May 18	June 4	June 29	July 9	August 3	August 25	October 4
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
21.8	20.5	16.4	17.3	21.9	11.5	8.5	16.8	9.0	7.1
17.0	18.2	16.2	16.3	17.7	10.1	9.5	12.9	10.2	7.7
11.1	14.7	14.8	13.1	14.0	11.2	10.4	9.7	9.9	7.9
9.2	9.2	12.3	9.2	....	11.6	8.9	10.9	9.5	7.9
11.1	11.1	10.7	10.6	9.3	11.0	11.9	12.3	12.4	9.8
10.6	11.9	11.0	10.9	10.0	11.2	10.6	12.3	12.9	10.5
9.6	....	....	....	....	....	....	10.1	....	8.8
8.9	....	....	....	....	....	....	9.3	....	8.4
8.6	....	....	....	....	....	....	8.1	....	9.2
8.4	....	....	....	....	....	....	7.7	....	7.9
....	....	....	....	....	....	....	....	....	7.7
....	....	....	....	....	....	....	....	....	7.2
....	....	....	....	....	....	....	....	....	7.1
....	....	....	....	....	....	....	....	....	6.6
....	....	....	....	....	....	....	....	....	5.6
16.6	17.8	15.8	15.9	17.9	10.9	9.5	13.1	9.7	7.6
13.1	14.4	13.6	12.9	14.6	11.1	10.0	12.5	10.7	8.5
11.6	....	....	....	....	....	....	11.0	....	8.5
....	....	....	....	....	....	....	....	....	7.3

TABLE V.—*Soil moisture determinations, 1909.*

Disked after binder, fall plowed. Oats every year.

Depth	March 30	April 12	May 3	May 18	June 4	June 29	July 9	August 4	August 25	October 4
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	18.3	12.5	15.0	14.9	20.8	10.9	7.3	11.7	11.2	10.5
2	15.1	15.4	15.1	15.1	17.8	10.2	7.7	8.9	9.8	8.5
3	10.5	10.0	11.7	11.3	10.4	10.5	8.0	8.4	9.1	8.0
4	10.4	9.6	9.4	10.0	9.3	10.4	8.7	8.4	11.6	8.7
5	13.6	12.7	11.8	12.5	11.7	12.7	11.1	11.5	12.5	9.6
6	14.1	15.2	12.9	13.0	12.2	13.7	10.9	10.5	....	12.0
7	12.6	....	....	....	....	....	....	10.9	....	10.2
8	10.4	....	....	....	....	....	....	9.2	....	9.2
9	9.7	....	....	....	....	....	....	8.2	....	8.5
10	9.2	....	....	....	....	....	....	7.3	....	7.9
11	....	....	....	....	....	....	....	....	....	7.2
12	....	....	....	....	....	....	....	....	....	6.9
13	....	....	....	....	....	....	....	....	....	5.8
14	....	....	....	....	....	....	....	....	....	5.3
15	....	....	....	....	....	....	....	....	....	5.6
3	14.6	12.6	13.9	13.7	16.3	10.5	7.7	9.7	11.5	5.7
6	13.7	12.2	12.7	12.8	13.7	11.4	9.0	11.9	11.3	7.9
10	12.4	....	....	....	....	....	....	9.5	....	9.3
15	....	....	....	....	....	....	....	....	....	8.1

TABLE VI.—*Soil moisture determinations, 1909.*

Plat C.—Oats 1908. Summer tilled 1909.

	Depth	March 30	April 12	May 6	May 18	June 4	June 29	July 9	August 4	August 25	October 5
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	18.4	18.1	16.1	16.4	21.3	19.6	13.9	17.2	18.3	15.0
	2	14.4	15.3	14.6	15.0	18.2	18.3	15.6	16.2	17.8	15.7
	3	9.3	9.6	9.0	9.7	9.9	17.1	14.8	16.2	16.8	15.2
	4	11.2	10.5	10.1	11.2	11.1	16.5	13.4	15.9	17.2	16.2
	5	16.1	15.3	14.8	15.6	14.9	18.5	15.0	19.2	20.4	19.6
	6	15.3	9.7	14.6	14.5	14.9	15.5	11.3	18.3	18.5	18.1
	7	11.8	......	......	......	......	......	......	14.7	......	14.8
	8	10.6	......	......	......	......	......	......	12.7	......	13.1
	9	10.4	......	......	......	......	......	......	11.3	......	12.3
	10	10.1	......	......	......	......	......	......	10.5	......	11.9
	11	......	......	......	......	......	......	......	......	......	10.6
	12	......	......	......	......	......	......	......	......	......	8.9
	13	......	......	......	......	......	......	......	......	......	7.9
	14	......	......	......	......	......	......	......	......	......	7.5
	15	......	......	......	......	......	......	......	......	......	6.6
Average to	3	14.0	14.3	13.2	13.7	16.5	18.3	14.8	16.2	17.6	15.3
Average to	6	14.1	13.1	13.2	13.7	15.1	17.6	14.0	17.2	18.2	16.6
Average to	10	12.8	......	......	......	......	......	......	15.2	......	15.9
Average to	15	......	......	......	......	......	......	......	......	......	12.9

TABLE VII.—*Soil moisture determinations, 1909.*

Plat D.—Summer tilled 1908. Oats 1909.

	Depth	March 30	April 12	May 6	May 18	June 4	June 29	July 9	August 4	August 25	October 5
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	18.6	18.2	15.6	16.9	21.7	8.9	....	8.3	10.3	8.6
	2	16.2	16.3	15.9	16.0	19.3	9.3	....	8.0	8.6	8.5
	3	15.0	15.2	15.1	15.4	16.5	9.8	....	7.5	8.9	8.7
	4	15.1	15.6	15.4	15.5	15.9	13.2	....	8.1	9.4	10.8
	5	17.8	17.2	17.0	17.8	17.4	16.0	....	10.8	12.9	15.3
	6	16.6	17.2	16.4	16.8	16.8	15.1	....	14.2	14.9	14.3
	7	14.3	....	....	....	....	....	....	13.2	....	12.0
	8	12.4	....	....	....	....	....	....	11.5	....	11.3
	9	11.4	....	....	....	....	....	....	10.9	....	11.3
	10	10.9	....	....	....	....	....	....	10.6	....	10.7
	11	....	....	....	....	....	....	....	....	....	10.0
	12	....	....	....	....	....	....	....	....	....	9.0
	13	....	....	....	....	....	....	....	....	....	8.4
	14	....	....	....	....	....	....	....	....	....	8.3
	15	....	....	....	....	....	....	....	....	....	7.9
Average to	3	16.6	16.6	15.5	16.1	19.2	9.3	....	7.9	9.3	8.6
Average to	6	16.6	16.6	15.9	16.4	17.9	12.1	....	9.5	10.8	11.0
Average to	0	14.8	....	....	....	....	....	....	10.3	....	11.2
Average to	5	....	....	....	....	....	....	....	....	....	10.3

TABLE VIII.—*Soil moisture determinations, 1907.*

Plat A.—Spring plowed. Corn every year.

	Depth	April 15	May 6	May 21	June 6	June 19	July 3	July 22	August 14	Sept. 13	October 13
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	14.1	14.8	15.9	21.4	20.6	18.4	15.7	10.2	11.9	12.3
	2	15.1	15.6	15.9	19.9	17.8	17.3	14.0	10.8	9.8	8.5
	3	13.9	14.4	14.7	15.7	16.7	15.8	14.8	11.3	9.4	8.2
	4	....	....	....	....	....	14.0	....	....	....	....
	5	....	....	....	....	....	14.7	....	....	....	....
	6	....	....	....	....	....	14.8	....	....	....	....
Average to	3	14.4	14.9	15.5	19.0	18.4	17.2	14.8	10.8	10.4	9.7
Average to	6	....	....	....	....	....	15.8	....	....	....	....
Plat B.—Fall plowed. Corn every year.											
	1	16.5	20.1	16.9	21.3	21.2	17.7	16.7	10.3	12.9	15.9
	2	16.2	16.9	15.6	19.2	18.1	17.1	15.6	12.0	9.2	8.5
	3	14.1	15.1	14.9	16.9	16.5	16.6	16.0	13.1	9.2	8.2
	4	....	....	....	....	....	14.9	....	....	....	....
	5	....	....	....	....	....	16.4	....	....	....	....
	6	....	....	....	....	....	16.6	....	....	....	....
Average to	3	15.6	17.4	15.8	19.1	18.6	17.1	16.1	11.8	10.4	10.9
Average to	6	....	....	....	....	....	16.6	....	....	....	....

VIII.—(Continued)—*Soil moisture determinations, 1907.*

.—Corn 1906. Summer tilled 1907.

	Depth	April 15	May 6	May 21	June 6	June 19	July 3	July 22	August 14	Sept. 13	October 13
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	16.7	18.1	16.4	20.9	19.8	17.7	18.0	15.6	17.8	17.2
	2	16.4	16.2	15.2	18.5	18.0	16.2	17.0	16.4	16.5	17.4
	3	14.1	14.8	14.6	16.5	16.8	15.9	16.2	15.4	15.6	15.5
	4	....	....	....	13.6	....	14.4	....	....	....	....
	5	....	....	....	15.2	....	14.8	....	....	....	....
	6	....	....	....	13.7	....	12.6	....	....	....	....
ge to	3	15.7	16.4	15.4	18.6	18.2	16.6	17.1	15.8	16.6	16.7
ge to	6	....	....	....	16.4	....	15.3	....	....	....	....

Summer tilled 1906. Corn 1907.

	Depth	April 15	May 6	May 21	June 6	June 19	July 3	July 22	August 14	Sept. 13	October 13
	1	16.1	18.9	16.9	22.1	21.4	17.8	16.6	8.8	11.1	16.0
	2	15.3	16.8	16.3	20.0	18.5	17.1	15.5	9.8	9.0	9.8
	3	13.3	15.0	15.5	17.5	16.6	16.2	15.5	11.8	9.2	9.1
	4	....	....	....	16.3	....	....	....	....	....	....
	5	....	....	....	18.0	....	....	....	....	....	....
	6	....	....	....	18.3	....	....	....	....	....	....
ge to	3	14.9	16.9	16.2	19.8	18.8	17.0	15.9	10.1	9.8	11.6
ge to	6	....	....	....	18.7	....	....	....	....	....	....

TABLE IX.—*Soil moisture determinations, 1908.*

	Depth	April 6	April 15	April 20	April 28	May 6	May 13	May 19
Plat A.—Spring plowed. Corn every year.								
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	14.1	13.1	14.5	14.6	21.9	17.2	19.3
	2	11.1	10.6	11.5	11.1	12.3	13.5	19.2
	3	9.2	9.0	9.0	9.3	9.4	9.3	10.4
	4	9.9	......	......	......	10.0	......	......
	5	13.4	.	......	......	13.7	....	......
	6	12.8	......	......	......	13.7	......	......
	7	......	......	......	......	......	......	......
	8	......	......	......	......	......	......	......
	9	......	......	......	......	......	......	......
	10	......	......	......	......	......	......	
Average to	3	11.5	10.9	11.7	11.7	14.5	13.3	16.3
Average to	6	11.8	......	....	...	13.5	......	......
Plat B.—Fall plowed. Corn every year.								
	1	14.4	13.2	13.8	14.0	20.9	18.8	19.3
	2	10.4	10.2	11.3	11.0	10.1	11.4	18.5
	3	9.1	9.0	9.0	9.3	8.9	9.3	10.8
	4	9.3	......	......	......	10.3	......	......
	5	13.1	......	......	....	13.3	......	......
	6	14.0	......	......	......	14.5	......	......
	7	......	......	......	......	......	......	......
	8	......	......	......	......	......	......	......
	9	......	......	......	......	......	......	......
	10	......	......	......	......	......	......	......
Average to	3	11.3	10.8	11.4	11.4	13.3	13.2	16.2
Average to	6	11.7	......	......	......	13.0	......	......
Plat C.—Summer tilled 1907. Corn 1908.								
	1	15.3	14.1	14.7	15.1	21.3	19.0	18.5
	2	15.7	15.0	15.6	15.7	15.8	16.8	20.4
	3	14.3	14.6	15.1	15.0	14.7	15.1	18.7
	4	14.4	....	......	......	14.5	......	......
	5	17.6	......	......	......	15.9	......	......
	6	17.2	......	......	......	17.4	......	......
	7	......	......	......	......	......	...	......
	8	......	......	......	......	......	......	......
	9	......	......	......	......	......	......	......
	10	......	......	......	......	......	......	......
Average to	3	15.1	14.6	15.1	15.3	17.3	17.0	19.2
Average to	6	15.8	......	......	......	16.6	....	......
Plat D.—Corn 1907. Summer tilled 1908.								
	1	13.7	13.3	12.4	12.8	20.1	18.4	19.9
	2	10.5	10.0	9.6	9.1	9.2	10.4	17.6
	3	9.6	8.8	8.6	8.8	9.1	9.1	9.6
	4	10.8	......	......	......	10.7	......	......
	5	14.8	......	......	......	14.5	......	......
	6	14.9	....	......	......	15.4	......	......
	7	......	......	......	......	......	......	......
	8	......	......	......	...	......	......	......
	9	......	......	......	......	......	......	......
	10	......	......	......	......	......	......	......
Average to	3	10.3	10.7	10.2	10.2	12.8	12.6	15.7
Average to	6	12.4	...	....	....	13.2	......	......

TABLE IX.—(Continued)—*Soil moisture determinations, 1908.*

Plat A.—Spring plowed. Corn every year.

	Depth	May 27	June 3	June 19	June 24	July 2	July 11	July 17
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	21.1	21.1	23.5	24.4	21.7	20.8	19.5
	2	18.9	18.4	21.7	20.4	18.4	17.8	17.9
	3	12.7	13.2	17.8	17.3	17.2	16.7	17.1
	4	......	9.4	......	......	13.4	......	......
	5	......	12.7	......	......	13.4	......	......
	6	......	13.7	......	......	13.2	......	......
	7	......	......	......	......	......	......	......
	8	......	......	......		......	......	......
	9	......	......	......	......	......	......	......
	10	......	......	......	......		......	......
Average to	3	17.6	17.6	21.0	20.7	19.1	18.4	18.2
Average to	6	......	14.8	......	......	16.2	......	......
Plat B.—Fall plowed. Corn every year.								
	1	21.6	20.8	23.1	23.7	21.4	20.2	19.0
	2	18.2	17.3	20.4	19.1	18.1	17.5	17.9
	3	12.1	12.6	14.7	15.5	17.0	16.1	17.1
	4	......	9.7	......	......	12.7	......	......
	5	......	13.3	......	......	14.2	......	......
	6	......	15.6	......	......	15.1	......	......
	7	......	......	......	......	......	......	......
	8	......	......	......	......	......	......	......
	9	......	......	......	......	.	......	......
	10	......	......	......	......	......	......	......
Average to	3	17.3	16.9	19.4	19.4	18.8	17.9	18.0
Average to	6	......	14.9	......	......	16.4	......	......
Plat C.—Summer tilled 1907. Corn 1908.								
	1	21.1	20.9	21.6	23.4	21.3	20.0	17.7
	2	19.9	19.3	21.2	20.9	18.5	18.5	17.6
	3	18.1	18.1	19.3	18.3	16.7	17.2	17.4
	4	......	16.3	......	......	17.0	......	......
	5	......	17.9	......	......	20.1	......	......
	6	......	18.7	......	......	19.9	......	......
	7	......	......	......	......	......	......	......
	8	......	......	......	......	......	......	......
	9	......	......	......	......	......	......	......
	10	......	......	......	......	......	......	......
Average to	3	19.7	19.4	20.7	20.9	18.8	18.6	17.6
Average to	6	......	18.5	......	......	18.9	......	......
Plat D.—Corn 1907. Summer tilled 1908.								
	1	21.2	20.5	23.4	22.1	21.9	20.2	18.7
	2	18.0	17.7	20.3	19.6	18.5	17.7	18.2
	3	10.5	11.6	15.4	17.5	17.0	16.4	16.2
	4	......	11.1	......	......	14.8	......	......
	5	......	15.2	......	......	15.0	......	......
	6	......	15.1	......	......	15.5	......	......
	7	......	......	......	......	......	......	......
	8	......	......	......	......	......	......	......
	9	......	......	......	......	......	......	......
	10	......	......	......	......	......	......	......

TABLE IX.—(Concluded)—*Soil moisture determinations, 1908.*

	Depth	July 23	July 27	August 3	August 15	August 21	Sept. 9	Sept. 23	Oct. 3
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Plat A.—Spring plowed. Corn every year.									
	1	21.7	19.2	13.2	11.9	10.9	7.3	7.7	7.0
	2	17.6	16.9	14.9	11.3	10.6	8.7	9.1	8.8
	3	16.5	16.5	15.8	12.8	11.4	9.1	8.8	8.6
	4	......	......	14.9	......	......	......	8.5	......
	5	......	......	16.4	......	......	......	11.3	......
	6	......	......	16.1	......	......	......	12.2	......
	7	......	......	......	......	......	......	10.2	......
	8	......	......	......	......	......	......	9.2	......
	9	......	......	......	......	......	......	8.6	......
	10	......	......	......	......	......	......	7.9	......
Av. to	3	18.6	17.5	14.6	12.0	11.0	8.5	9.4	8.1
Av. to	6	......	......	15.2	......	......	......	......	......
Plat B.—Fall plowed. Corn every year.									
	1	20.9	17.3	11.8	12.3	10.5	8.3	7.8	7.4
	2	17.5	16.0	13.7	11.5	10.2	8.4	8.8	8.8
	3	15.8	16.0	14.9	12.5	11.1	9.1	9.3	8.6
	4	......	......	15.5	......	......	......	9.1	......
	5	......	......	14.4	......	......	......	13.2	......
	6	......	......	14.6	......	......	......	13.9	......
	7	......	......	......	......	......	......	11.7	......
	8	......	......	......	......	......	......	10.4	......
	9	......	......	......	......	......	......	9.8	......
	10	......	......	......	......	......	......	9.4	......
Av. to	3	18.1	16.4	13.5	12.1	10.6	8.6	10.3	8.3
Av. to	6	......	......	14.2	......		....	......	......
Plat C.—Summer tilled 1907. Corn 1908.									
	1	20.5	18.2	12.4	10.7	11.0	8.4	7.5	7.0
	2	17.8	17.5	13.9	11.3	10.0	9.5	9.2	9.0
	3	16.6	16.9	14.3	13.0	11.3	9.3	9.1	9.1
	4	......	......	15.7	......	......	15.0	9.9	......
	5	......	......	18.5	......		14.8	14.9	......
	6	......	......	17.2	......	......	16.2	15.0	......
	7	......	......	......	......	......	..	13.0	......
	8	......	......	......	......	......	......	12.7	......
	9	......	......	......	......	......	......	12.4	......
	10	......	......	......	..	......	......	12.0	......
Av. to	3	18.3	17.5	13.5	11.7	10.8	9.0	11.6	8.4
Av. to	6	......	......	15.3	......	......	12.2	......	......
Plat D.—Corn 1907. Summer tilled 1908.									
	1	21.9	19.9	16.3	17.5	16.1	15.4	14.0	12.5
	2	19.1	18.2	17.4	16.3	15.4	16.3	15.5	14.6
	3	16.4	16.3	16.2	15.0	14.5	15.6	15.2	14.1
	4	......	......	14.5	......	......	......	14.6	......
	5	......	......	15.8	......	......	......	17.4	......
	6	......	......	16.1	......	......	......	17.4	......
	7	......	......	......	......	......	......	14.1	......
	8	......	......	......	......	......	......	12.0	......
								11	......

TABLE X.—*Soil moisture determinations, 1909.*

ng plowed. Corn every year.

Depth	March 29	April 15	May 4	May 18	June 4	June 28	July 7	July 22	August 25	October 2
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	20.2	18.8	17.5	15.2	22.2	19.0	17.3	19.1	11.6	9.0
2	12.5	14.9	13.9	12.7	18.4	17.3	16.6	17.1	10.7	9.3
3	10.2	10.3	9.3	9.4	11.4	16.6	16.2	16.5	11.1	9.0
4	9.6	9.1	10.0	8.7	9.2	15.5	14.8	16.0	11.8	9.8
5	12.4	11.9	12.5	11.4	12.0	15.0	13.5	17.5	14.7	13.6
6	11.7	11.7	12.8	11.4	12.9	15.3	11.7	15.3	13.9	12.0
7	9.7	......	10.4	......	......	......	......	......	......	9.8
8	9.3	......	9.7	......	......	......	......	......	......	8.6
9	8.7	......	9.0	......	......	......	......	......	......	7.9
10	8.2	......	8.8	......	......	......	......	......	......	7.3
11	......	......	7.9	......	......	......	......	......	......	6.6
12	......	......	7.4	......	......	......	......	......	......	6.0
13	......	......	7.1	......	......	......	......	......	......	5.7
14	......	......	6.6	......	......	......	......	......	......	5.7
15	......	......	7.1	......	......	......	......	......	......	5.5
3	14.3	14.7	13.6	12.4	17.3	17.6	16.7	17.2	11.1	9.1
6	12.8	12.8	12.5	11.5	14.5	16.5	15.0	16.8	12.3	10.5
10	11.3	......	11.4	......	......	......	......	......	......	9.6
15	......	......	......	......	......	......	......	......	......	8.4

TABLE XI.—*Soil moisture determinations, 1909.*

wed. Corn every year.

March 29	April 15	May 4	May 18	June 4	June 28	July 7	July 22	August 21	October 2
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
19.4	18.6	15.1	14.5	21.5	18.7	17.6	19.4	11.3	8.8
12.9	14.3	13.9	13.3	18.2	17.6	16.8	17.6	10.6	9.1
9.5	9.3	9.1	8.9	10.5	16.9	15.2	17.3	11.1	8.9
9.9	9.4	9.1	8.7	9.0	12.9	13.9	16.7	12.1	10.0
13.7	12.5	12.1	12.0	11.9	13.0	14.0	17.9	16.1	13.5
14.6	13.6	13.5	12.8	14.4	14.5	13.6	16.3	15.7	14.3
12.2	....	11.1	....	....	....	....	....	....	12.0
10.8	....	10.9	....	....	....	....	....	....	10.5
10.4	....	10.6	....	....	....	....	....	....	10.0
10.0	....	10.2	....	....	....	....	....	....	9.3
....	....	9.4	....	....	....	....	....	....	....
....	....	8.9	....	....	....	....	....	....	....
....	....	8.5	....	....	....	....	....	....	....
....	....	8.2	....	....	....	....	....	....	....
....	....	8.1	....	....	....	....	....	....	....
13.9	14.0	12.7	12.2	16.7	17.7	16.5	18.1	11.0	8.9
13.3	13.0	12.1	11.7	14.3	15.6	15.2	17.5	12.8	10.8
12.3	....	11.6	....	....	....	....	....	....	10.6
....	....	10.7	....	....	....	....	....	....	9.8

TABLE XII.—*Soil moisture determinations, 1909.*

1908. Summer tilled 1909.

Depth	March 29	April 15	May 4	May 18	June 4	June 28	July 7	July 22	August 25	October 14
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	19.5	17.6	15.2	14.7	21.4	18.6	17.4	19.5	17.9	17.0
2	15.1	15.6	15.2	14.4	18.3	17.6	17.1	18.3	16.6	16.5
3	9.6	11.5	11.6	11.3	12.8	16.2	16.0	17.6	15.2	14.9
4	10.2	11.8	12.5	11.6	12.2	16.1	17.1	18.1	16.8	16.5
5	13.6	15.3	14.5	14.8	15.3	17.0	17.8	20.9	19.2	19.8
6	15.1	14.6	14.5	14.1	14.8	15.0	17.0	18.8	18.0	17.2
7	12.9	......	12.2	......	......	......	......	......	......	14.7
8	11.9	......	10.8	......	......	......	......	......	......	13.8
9	11.3	......	10.5	......	......	......	......	......	......	13.4
10	10.9	......	10.3	......	......	......	......	......	......	12.9
11	......	......	9.6	......	......	......	......	......	......	11.0
12	......	......	8.7	......	......	......	......	......	......	10.6
13	......	......	7.8	......	......	......	......	......	......	9.7
14	......	......	7.0	......	......	......	......	......	......	7.6
15	......	......	6.7	......	......	......	......	......	......	6.8
age to 3	14.7	14.9	14.0	13.5	17.5	17.5	16.8	15.1	16.6	16.1
rage to 6	13.7	14.4	13.9	13.5	15.8	16.8	17.1	18.9	17.3	16.9
erage to 10	13.0	......	12.7	......	......	......	......	......	......	15.7
erage to 15	......	......	11.1	......	......	......	......	......	......	13.5

TABLE XIII.—*Soil moisture determinations, 1909.*

Plat D.—Summer tilled 1908. Corn 1909.

	Depth	March 29	April 15	May 4	May 18	June 4	June 28	July 7	July 22	August 25	October 14
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	19.4	18.4	17.5	15.4	21.5	18.7	17.5	18.8	12.4	10.1
	2	16.7	16.4	15.9	15.8	19.4	17.8	17.2	18.0	12.9	9.7
	3	14.9	15.0	14.7	15.3	16.7	16.9	16.5	17.0	12.9	10.0
	4	15.1	14.3	14.7	14.8	14.7	17.1	17.3	17.2	14.6	13.1
	5	18.8	17.7	17.2	17.5	17.7	20.0	20.4	21.1	18.8	16.8
	6	17.8	17.6	15.7	16.2	17.9	19.2	19.2	19.1	18.3	16.1
	7	14.9	....	14.1	....	....	....	....	....	....	13.6
	8	13.0	....	12.7	....	....	....	....	....	....	12.3
	9	12.5	....	11.9	....	....	....	....	....	....	12.0
	10	11.7	....	11.1	....	....	....	....	....	....	11.6
	11	....	....	10.0	....	....	....	....	....	....	10.9
	12	....	....	10.0	....	....	....	....	....	....	10.4
	13	....	....	9.3	....	....	....	....	....	....	9.2
	14	....	....	8.6	....	....	....	....	....	....	7.9
	15	....	....	8.2	....	....	....	....	....	....	8.4
Average to	3	17.0	16.6	16.0	15.5	19.1	17.8	17.0	17.9	12.7	9.9
Average to	6	17.2	16.6	15.9	15.8	18.0	18.3	18.0	18.5	15.0	12.6
Average to	10	15.5	....	14.6	....	....	....	....	....	....	12.5
Average to	15	....	....	12.8	....	....	....	....	....	....	11.5

TABLE XIV.—*Soil moisture determinations, 1907.*

Plat A.—Spring plowed. Spring wheat every year.

	Depth	April 7	April 23	May 6	May 21	June 6	August 24
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	16.4	15.5	16.7	16.0	20.4	7.7
	2	16.9	16.4	16.1	15.8	17.3	8.2
	3	15.8	16.0	14.7	15.8	14.5	8.4
	4	....	....	....	....	....	8.9
	5	....	....	....	....	....	10.5
	6	....	....	....	....	....	12.4
Average to	3	16.4	16.0	15.8	15.9	17.4	8.1
Average to	6	....	....	....	....	....	9.3
Plat B.—Disked after binder and fall plowed. Spring wheat every year.							
	1	16.5	14.1	19.7	15.7	20.5	9.2
	2	16.4	13.9	15.8	15.6	17.8	8.5
	3	15.9	15.4	14.7	15.7	15.9	8.5
	4	....	....	....	....	....	9.2
	5	....	....	....	....	....	12.6
	6	....	....	....	....	....	12.2
Average to	3	16.3	14.5	16.7	15.7	18.1	8.7
Average to	6	....	....	....	....	....	10.0
Plat C.—Spring wheat 1906. Summer tilled 1907.							
	1	15.6	12.3	19.2	17.6	21.9	19.9
	2	16.6	12.7	16.5	17.1	20.0	18.2
	3	15.5	12.3	15.5	15.9	17.6	16.8
	4	....	....	....	....	....	15.9
	5	....	....	....	....	....	19.4
	6	....	....	....	....	....	17.0
Average to	3	15.9	12.4	17.1	16.9	19.8	18.3
Average to	6	....	....	....	....	....	17.9
Plat D.—Summer tilled 1906. Spring wheat 1907.							
	1	15.7	15.0	19.6	17.4	20.1	7.8
	2	16.9	15.6	17.1	16.6	17.8	8.2
	3	15.9	15.4	15.2	15.9	15.1	7.9
	4	....	....	....	....	....	8.6
	5	....	....	....	....	....	12.6
	6	....	....	....	....	....	13.9
Average to	3	16.2	15.3	17.3	16.6	17.7	8.0
Average to	6	....	....	....	....	....	9.8

TABLE XV.—*Soil moisture determinations, 1908.*

Plat A.—Spring plowed. Spring wheat every year.

	Depth	April 4	May 7	June 3	July 7	August 5	Sept. 11
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	14.2	17.6	16.9	14.3	7.2	6.7
	2	11.0	8.9	12.8	9.3	8.3	8.0
	3	11.0	8.2	8.7	8.6	8.1	8.5
	4	10.3	9.1	9.5	9.0	8.4	8.3
	5	11.6	10.9	11.0	10.6	10.0	9.8
	6	12.1	12.7	13.2	11.9	11.8	11.9
	7	....	....	....	....	....	10.8
	8	....	....	....	....	....	9.2
	9	....	....	....	....	....	8.2
	10	....	....	....	....	....	8.0
Average to	6	11.7	11.2	12.0	10.6	9.0	8.8
Average to	10	....	....	....	....	....	8.9
Plat B.—Disked after binder and fall plowed. Spring wheat every year.							
	1	14.0	18.7	17.8	12.1	7.3	9.3
	2	12.1	11.9	14.6	8.7	7.7	8.0
	3	8.7	8.6	10.3	8.8	7.7	8.4
	4	9.3	9.5	9.4	9.6	8.7	9.9
	5	12.1	11.0	12.2	12.9	11.3	13.2
	6	14.3	12.2	15.2	15.4	14.1	14.7
	7	....	....	....	....	....	12.8
	8	....	....	....	....	....	11.3
	9	....	....	....	....	....	10.9
	10	....	....	....	....	....	10.5
Average to	6	11.8	12.0	13.3	11.3	9.5	10.6
Average to	10	....	....	....	....	....	10.9
Plat C.—Summer tilled 1907. Spring wheat 1908.							
	1	15.9	19.4	15.4	12.6	8.1	10.0
	2	15.7	15.6	14.0	9.7	7.8	8.7
	3	15.4	14.1	14.9	10.1	7.2	8.2
	4	14.9	14.5	14.1	10.7	8.0	9.0
	5	18.9	16.4	17.4	15.7	13.3	13.2
	6	18.0	16.2	18.0	16.0	15.1	14.3
	7	....	....	....	....	....	11.6
	8	....	....	....	....	....	10.8
	9	....	....	....	....	....	11.5
	10	....	....	....	....	....	10.7
Average to	6	16.5	16.0	15.6	12.5	9.9	10.6
Average to	10	....	....	....	....	....	10.8
Plat D.—Spring wheat 1907. Summer tilled in 1908.							
	1	14.6	19.7	21.1	22.5	16.1	14.8
	2	11.8	13.2	18.3	18.4	16.8	15.9
	3	8.8	9.5	13.5	17.5	16.3	15.6
	4	10.7	11.7	12.0	16.2	16.0	16.4
	5	15.5	14.2	16.2	17.8	18.6	20.0
	6	15.0	14.4	15.3	15.7	16.9	18.1
	7	....	....	....	....	....	13.8
	8	....	....	....	....	....	11.8
	9	....	....	....	....	....	11.1
	10	....	....	....	....	....	11.0
Average to	6	12.7	13.8	16.1	18.0	16.8	16.8
Average to	10	....	....	....	....	....	14.9

TABLE XVI.—*Soil moisture determinations, 1909.*

-Spring plowed. Spring wheat every year.

	Depth	March 26	April 12	May 3	May 18	June 4	July 12	August 2	August 25	October 6
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	26.7	20.6	18.2	16.9	21.1	21.0	10.6	9.8	6.1
	2	19.6	18.3	17.3	16.9	17.5	11.1	8.9	9.4	7.7
	3	14.6	16.9	15.8	15.8	16.9	9.6	8.6	9.1	8.8
	4	11.4	12.2	12.2	12.5	13.0	10.3	9.3	9.5	8.7
	5	9.0	11.8	10.0	11.7	12.1	10.7	9.7	11.9	9.7
	6	11.1	12.2	10.7	11.1	13.0	12.6	12.7	13.7	9.9
	7	10.6	....	....	....	....	....	11.5	....	8.5
	8	8.8	....	....	....	....	....	9.2	....	7.8
	9	8.7	....	....	....	....	....	8.8	....	7.4
	10	8.8	....	....	....	....	....	8.3	....	6.7
to....	6	15.4	15.3	14.0	14.2	15.6	12.6	10.0	10.6	8.5
to....	10	12.9	....	....	....	....	....	9.8	....	8.1

-Disked and fall plowed. Spring wheat every year.

	Depth	March 26	April 12	May 3	May 18	June 4	July 12	August 2	August 25	Oct. 14
	1	18.8	17.4	15.4	15.1	19.4	21.5	11.3	10.1	7.7
	2	14.6	15.1	14.4	14.4	16.5	12.3	9.0	9.4	7.8
	3	9.7	9.5	9.4	9.5	10.5	8.6	8.3	9.0	8.1
	4	10.6	10.3	9.6	10.8	10.4	9.9	9.0	9.7	8.7
	5	12.6	12.9	12.0	13.5	13.5	11.8	10.7	11.4	10.3
	6	14.4	15.7	15.3	14.9	16.0	14.5	14.8	15.2	13.5
	7	13.6	....	....	....	....	....	14.0	....	11.4
	8	11.7	....	....	....	....	....	12.2	....	10.2
	9	11.2	....	....	....	....	....	11.4	....	10.0
	10	10.5	....	....	....	....	....	11.2	....	9.8
to....	6	13.6	13.5	12.7	13.0	14.4	13.1	10.3	10.8	9.3
to....	10	12.8	....	....	....	....	....	11.2	....	9.8

TABLE XVI.—(Continued.)—*Soil moisture determinations, 1909.*

Plat C.—Spring wheat 1908. Summer tilled 1909.

	Depth	March 26	April 12	May 3	May 18	June 8	July 12	August 2	August 25	October 14
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	19.2	17.6	16.6	15.6	21.2	23.9	18.0	20.3	14.7
	2	14.1	14.0	14.9	13.5	17.9	21.5	16.9	17.2	15.0
	3	8.8	8.8	9.6	8.6	10.2	18.9	15.8	16.1	14.0
	4	10.2	9.7	10.1	9.4	9.3	17.6	16.7	16.8	15.0
	5	14.4	14.3	13.7	13.5	13.2	17.8	18.8	19.9	18.2
	6	15.2	15.7	13.8	13.8	13.8	15.8	18.4	18.6	16.3
	7	12.3	....	....	....	....	....	15.1	....	14.5
	8	11.2	....	....	....	....	....	13.3	....	13.4
	9	10.6	....	....	....	....	....	11.7	....	11.9
	10	10.5	....	....	....	....	....	13.5	....	10.7
Average to....	6	15.3	13.4	13.1	12.4	14.3	19.3	17.4	18.2	15.5
Average to....	10	12.7	....	....	....	....	....	15.8	....	14.4
Plat D.—Summer tilled 1908. Spring wheat 1909.										
	1	19.8	18.5	17.4	15.8	19.7	22.7	11.1	10.5	10.7
	2	16.0	16.5	16.0	15.4	17.3	17.7	9.7	9.4	10.5
	3	15.4	15.8	15.2	15.2	15.3	9.9	8.5	9.0	9.7
	4	16.0	16.9	16.0	15.5	14.7	11.6	9.0	9.0	10.3
	5	19.5	20.3	19.3	18.9	17.7	15.4	14.3	15.0	14.1
	6	17.8	17.9	17.1	16.7	16.7	14.8	14.9	14.9	14.9
	7	14.1	....	....	....	....	....	13.1	....	13.0
	8	13.0	....	....	....	....	....	12.0	....	11.9
	9	12.2	....	....	....	....	....	11.8	....	11.6
	10	11.8	....	....	....	....	....	11.8	....	11.5
Average to...	6	17.4	17.7	16.8	16.3	16.9	15.4	11.3	11.3	11.7
Average to....	10	15.6	....	....	....	....	....	11.6	....	11.8

TABLE XVII.—*Soil moisture determinations, 1908.*

Plat A.—Spring plowed and harrowed. Barley every year.

	Depth	April 15	May 9	May 22	June 8	June 25	August 17	Sept. 29
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	9.7	15.4	15.7	13.4	18.6	7.4	6.6
	2	8.7	9.6	13.6	11.3	12.1	8.5	8.2
	3	8.2	8.7	7.7	10.0	10.6	8.5	8.5
	4	......	9.8	......	10.8	......	9.1	9.2
	5	......	11.6	......	11.7	......	11.2	11.2
	6	......	15.2	......	14.4	......	14.6	13.8
	7	......	......	......	......	......	......	12.1
	8	......	......	......	......	......	......	10.4
	9	......	......	......	......	......	......	9.9
	10	......	......	......	......	......	......	9.6
Average to	3	8.9	11.2	12.3	11.6	13.8	8.1	7.8
Average to	6	......	11.7	......	11.9	......	9.9	19.2

Plat B.—Disked after binder and fall plowed. Barley every year.

	Depth	April 15	May 9	May 22	June 8	June 25	August 17	Sept. 29
	1	12.9	16.2	15.5	11.6	19.9	12.8	11.1
	2	12.5	13.7	16.1	10.3	13.8	9.9	11.8
	3	9.7	10.4	10.6	10.5	11.8	8.9	10.2
	4	......	11.0	......	12.5	......	9.7	11.7
	5	......	13.6	......	15.6	......	12.8	14.4
	6	......	16.7	......	16.9	......	15.3	15.8
	7	......	......	......	......	......	......	13.6
	8	......	......	......	......	......	......	11.1
	9	......	......	......	......	......	......	10.9
	10	......	......	......	......	......	......	10.6
Average to	3	11.7	13.4	14.1	10.8	15.2	10.5	11.0
Average to	6	......	13.6	......	12.9	......	11.6	12.5

Plat C.—Summer tilled 1907. Barley in 1908.

	Depth	April 15	May 9	May 22	June 8	June 25	August 17	Sept. 29
	1	14.1	17.2	13.5	11.5	22.5	11.6	9.2
	2	15.0	15.4	15.8	10.5	13.9	10.1	9.8
	3	14.6	14.1	16.1	11.7	13.5	9.9	9.8
	4	......	15.5	......	14.1	......	11.0	10.5
	5	......	18.8	......	18.3	......	15.7	15.2
	6	......	18.5	......	16.1	......	15.6	15.0
	7	......	......	......	......	......	......	12.2
	8	......	......	......	......	......	......	10.9
	9	......	......	......	......	......	......	11.1
	10	......	......	......	......	......	......	11.4
Average to	3	14.6	15.9	15.1	11.2	16.6	10.2	9.6
Average to	6	......	16.6	......	13.7	......	12.3	13.3

TABLE XVIII.—*Soil moisture determinations, 1907.*

Plat A.—Spring plowed and harrowed. Barley every year.

	Depth	April 7	April 23	May 6	May 21	June 6	August 24
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	15.6	14.0	19.9	16.4	20.6	8.1
	2	16.4	13.6	16.3	16.2	18.5	8.4
	3	15.2	13.8	15.4	15.2	15.8	8.6
	4	....	....	....	....	....	9.2
	5	....	....	....	....	....	12.7
	6	....	....	....	....	....	14.9
Average to	3	15.7	13.8	17.2	15.9	18.3	8.4
Average to	6	....	....	....	....	....	10.3
Plat B.—Disked after binder and fall plowed. Barley every year.							
	1	15.6	15.8	18.2	16.9	20.8	9.5
	2	16.5	16.4	15.5	15.6	19.1	9.2
	3	16.0	15.5	15.9	14.8	16.9	8.8
	4	....	....	....	....	....	9.6
	5	....	....	....	....	....	14.6
	6	....	....	....	....	....	16.7
Average to	3	16.0	15.9	16.5	15.8	18.9	9.2
Average to	6	....	....	....	....	....	11.4
Plat C.—Barley 1906. Summer tilled 1907.							
Plat D.—Barley. Summer tilled 1906. Spring 1907.							
	1	16.6	15.3	16.9	16.3	22.3	9.6
	2	16.9	15.4	16.4	16.1	20.3	11.5
	3	15.3	15.1	15.4	15.3	18.2	10.2
	4	....	....	....	....	....	12.3
	5	....	....	....	....	....	14.9
	6	....	....	....	....	....	17.4
Average to	3	16.3	15.3	16.2	15.9	20.3	10.4
Average to	6	....	....	....	....	....	12.5

TABLE XIX.—*Soil moisture determinations, 1909.*

Plat A.—Spring plowed. Barley every year.

	Depth	April 19	June 9	July 12	July 22	August 26	October 15
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	18.4	20.5	22.2	15.2	13.3	8.7
	2	17.1	17.8	14.9	14.6	12.9	8.9
	3	13.7	15.8	11.6	11.2	11.6	11.7
	4	9.4	11.5	9.9	9.6	10.3	10.9
	5	11.7	11.1	11.5	12.2	12.0	12.2
	6	14.8	13.7	14.1	15.2	15.7	9.6
	7	12.6	....	....	13.0	....	12.2
	8	10.0	....	....	10.5	....	9.7
	9	9.8	....	....	9.6	....	9.7
	10	9.5	....	....	9.3	....	9.7
	11	9.2	....	....	....	....	8.8
	12	8.8	....	....	....	....	8.5
	13	8.4	....	....	....	....	8.7
	14	8.1	....	....	....	....	8.5
	15	8.3	....	....	....	....	8.4
Average to	3	16.4	18.0	16.2	13.7	12.6	13.1
Average to	6	14.2	15.1	14.0	13.0	12.6	10.3
Average to	10	12.7	....	....	12.0	....	10.3
Average to	15	11.6	....	....	....	....	9.8

TABLE XX.—*Soil moisture determinations, 1909.*

Plat B.—Disked after binder and fall plowed. Barley every year.

	Depth	April 19	June 9	July 12	July 22	August 26	October 15
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	18.6	20.7	20.2	12.7	13.2	10.9
	2	14.8	18.2	12.1	16.0	9.8	10.0
	3	11.8	15.1	8.8	9.4	8.7	9.0
	4	11.3	12.5	9.8	9.2	9.0	9.3
	5	15.2	14.5	12.5	11.9	12.4	12.0
	6	16.3	15.5	14.2	14.3	13.3	14.4
	7	13.1	....	....	12.8	....	11.2
	8	11.2	....	....	10.6	....	10.6
	9	10.8	....	....	10.4	....	10.4
	10	10.2	....	....	10.1	....	9.7
	11	9.9	....	....	....	....	8.8
	12	9.4	....	....	....	....	8.7
	13	9.3	....	....	....	....	8.9
	14	8.7	....	....	....	....	8.3
	15	8.5	....	....	....	....	7.4
Average to	3	15.0	18.0	13.7	12.7	10.6	9.9
Average to	6	14.7	16.7	12.9	12.3	11.1	10.9
Average to	10	13.3	....	....	11.7	....	10.8
Average to	15	11.9	....	....	....	....	9.9

TABLE XXI.—*Soil moisture determinations, 1909.*

Plat C.—Barley in 1908. Summer tilled 1909.

	Depth	April 19	June 9	July 12	July 23	August 26	October 16
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	17.7	21.8	23.6	19.1	17.3	15.5
	2	15.5	18.7	21.4	18.3	14.9	15.8
	3	11.3	13.0	20.1	18.0	15.1	15.4
	4	14.3	12.6	18.5	19.6	15.4	18.1
	5	14.7	16.5	20.6	23.3	19.1	20.9
	6	15.9	15.8	19.2	21.1	15.5	18.9
	7	12.4	....	....	17.8	....	15.6
	8	10.9	....	....	15.1	....	13.5
	9	10.9	....	....	13.6	....	13.2
	10	11.1	....	....	13.2	....	12.7
	11	10.4	....	....	....	....	12.2
	12	10.3	....	....	....	....	11.8
	13	10.2	....	....	....	....	11.7
	14	10.0	....	....	....	....	11.2
	15	....	....	....	....	....	11.1
Average to	3	14.8	17.8	21.7	18.4	15.8	15.6
Average to	6	11.6	16.4	20.6	19.9	16.2	17.4
Average to	10	13.5	....	....	17.9	....	16.0
Average to	15	12.4	....	....	....	.....	14.5

TABLE XXII.—*Soil moisture determinations, 1909.*

Plat D.—Summer tilled 1908. Barley 1909.

	Depth	April 19	June 9	July 12	July 23	August 26	October 16
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	18.1	20.1	23.4	14.8	10.8	7.8
	2	16.5	18.0	18.2	14.4	10.2	11.7
	3	15.4	16.2	13.8	11.7	8.9	11.6
	4	15.4	14.9	11.9	10.5	8.3	10.4
	5	18.8	17.7	17.9	15.3	12.7	12.9
	6	18.5	19.0	18.7	16.9	13.7	15.6
	7	16.2	....	....	14.3	....	13.7
	8	13.8	....	....	12.9	....	11.7
	9	12.5	....	....	13.0	....	12.7
	10	12.2	....	....	12.8	....	11.3
	11	12.2	....	....	....	....	11.4
	12	11.8	....	....	....	....	5.5
	13	11.7	....	....	....	....	10.9
	14	11.0	....	....	....	....	10.6
	15	11.2	....	....	....	....	10.9
Average to	3	16.7	18.1	18.5	13.6	9.9	10.4
Average to	6	17.1	17.7	17.3	13.9	10.8	11.7
Average to	10	15.7	....	....	13.5	....	11.9
Average to	15	14.4	....	....	....	....	11.2

TABLE XXIII.—*Soil moisture determinations, 1908-1909.*

Field I.—In brome grass 1905 to 1909.

1908	Depth	March 16	April 18	May 11	June 12	June 22	July 20	Oct. 6
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	12.2	8.0	12.4	14.3	14.1	10.6	5.4
	2	8.6	7.3	7.3	8.5	9.7	10.7	6.6
	3	7.8	7.9	7.0	6.7	6.8	9.6	6.2
	4	7.7	7.0	6.8	6.4	6.0	7.1	6.2
	5	8.2	6.5	6.9	6.7	6.0	6.8	6.3
	6	8.5	6.7	7.0	6.7	6.7	6.8	6.5
	7	. . .	......	......	.....	......	......	7.2
	8	......	......	......	......	.....	.....	7.7
	9	......	.....	.....	.....	.....	.....	8.6
	10	......	.....	.....	......	.....	......	8.1
Average to	6	8.8	7.2	7.9	8.2	8.2	8.6	6.2
Average to	10	....	......	......	.....	......	......	6.9

1909	Depth	April 19	May 8	June 14	July 17	July 26	Sept. 9
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	17.5	11.8	17.5*	18.8	19.5	6.9
	2	15.9	14.5	18.2	14.8	10.8	6.7
	3	12.7	12.0	14.7	11.4	9.6	6.3
	4	7.1	8.1	10.7	10.7	8.4	6.5
	5	7.0	6.8	9.3	10.8	9.4	7.0
	6	7.0	6.9	7.7	10.4	9.3	6.7
	7	7.4	....	....	....	6.8	6.3
	8	7.3	....	....	....	6.1	6.4
	9	7.7	....	....	....	6.4	6.3
	10	7.4	....	....	....	7.1	6.2
Average to	6	11.2	10.0	13.0	12.8	9.7	6.7
Average to	10	9.7	.. .	....	......	8.4	6.5

*An old irrigation ditch just above this field broke during a heavy rain June 9 and this field was flooded, which probably accounts for the increased water content.

TABLE XXIV.—*Soil moisture determinations, 1908-1909.*

Native sod on the table-land.

1908	Depth	April 23	May 12	June 13	June 27	July 11	Aug. 8	Sept. 25
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	15.5	20.3	27.3	18.8	17.2	11.3	9.0
	2	10.9	9.5	22.1	17.3	18.2	13.2	8.1
	3	10.2	9.5	14.4	13.0	17.2	14.7	9.1
	4	9.4	9.2	10.2	9.4	15.8	14.0	8.6
	5	8.5	8.6	8.3	9.5	11.6	11.3	8.0
	6	7.7	8.0	7.6	9.3	8.4	9.0	7.3
	7	.....	......	......	......	......	......	6.9
	8	......	......	......	....	.....	.....	6.8
	9	. ....	......	......	......	......	......	6.6
	10	.....	....	. ....	......	......	.....	6.1
Average to	6	10.4	10.9	15.0	12.9	14.7	12.3	8.4
Average to	10	.....	. ....		.....	......	....	7.6

1909	Depth	April 27	June 16	July 19	August 14	October 23
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	21.2	21.6	19.6	10.8	7.2
	2	18.5	20.3	19.0	12.3	8.0
	3	9.9	18.5	16.1	14.2	8.5
	4	7.7	17.2	14.2	13.9	8.9
	5	7.4	11.5	14.4	12.4	8.6
	6	7.3	6.7	10.9	11.6	9.4
	7	7.1	... .	....	10.0	9.0
	8	7.6	... .	... .	8.3	8.1
	9	7.1	....	....	7.6	7.5
	10	7.1	....	... .	6.4	6.2
Average to..........	6	12.0	16.0	15.7	12.5	8.4
Average to..	10	10.1	....	....	10.8	8.3

TABLE XXVI.—*Showing maximum water-holding capacity of this type of soil, 1908-1909.*

Hard table-land. Buffalo grass sod.

	Depth	1908					1909				
		Sept. 9	Sept. 17	October 1	October 9	October 20	March 19	April 22	June 1	July 30	Sept. 22
	Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
	1	6.7	9.1	14.8	12.4	20.6	22.4	16.6	22.6	13.7	13.7
	2	7.4	17.9	15.7	16.0	19.7	16.3	16.8	19.1	14.8	14.1
	3	7.4	19.3	15.9	16.0	18.9	15.3	15.6	16.3	15.5	14.2
	4	7.4	19.7	16.2	15.7	17.9	14.6	15.9	16.0	15.8	14.3
	5	8.5	23.7	19.3	19.6	19 4	17.5	16.0	16.6	18.7	17.5
	6	9.1	23.0	19.5	20.1	19.2	18.0	15.0	17.7	23.0	17.9
	7	9.9	22.2	18.9	19.0	18.1	17.1	15.6	16.6	19.5	17.8
	8	11.8	21.1	18.2	17.5	18.2	16.3	14.0	15.2	19.7	17.3
	9	11.8	21.5	17.3	16.5	15.4	14.4	12.4	14.8	17.4	15.2
	10	11.2	22.9	18.3	17.0	16.0	13.9	12.3	12.8	18.5	14.9
	11	....	....	....	....	....	....	15.6	16.4	....	19.6
	12	....	....	....	....	....	....	14.1	17.7	....	18.2
	13	....	....	....	....	....	....	11.0	15.4	....	16.4
	14	....	....	....	....	....	..	14.4	15.9	....	18.3
	15	....	....	....	....	....	....	16.1	15.0	....	18.2
Average to	10	9.1	20.0	17.4	17.0	18.3	16.6	15.0	16.7	17.7	16.9

XXVII.—*Daily rainfall from March 1 to September 30, for the years 1907, 1908, and 1909.*

March			April			May			June			July			August			September		
907	1908	1909	1907	1908	1909	1907	1908	1909	1907	1908	1909	1907	1908	1909	1907	1908	1909	1907	1908	1909
....	....	....	....	....	....	....	....	....	....	.09	.46	....	.41	....	....	....	.39	1.27	....	.30
....	....	....	....	....	....	.35	....	....	.81	T	.13	.05	.01	....	.63	....	.08	....	....	....
....	....	....	....	....	T	.08	.12	....	.29	T	....	....	....	....	....	....	....	....	....	....
....	T	....	....	....	....	T	1.16	....	T	....	....	....	....	....	....	....	....	....	....	.40
T*	.10	T	....	....	.11	T	.19	....	.01	....	.16	1.60	.22	.11	....	.01	....	....	....	.02
....	.04	....	....	....	.23	T	....	....	T	.25	T	.02	.66	....	....	.34	....	....	....	....
....	T	.13	....	T	....	....	....	....	T	.03	.44	T	....	T	....	....	T	....	....	.01
....	....	....	....	....	....	.01	....	....	.19	.02	T	.93	....	T	....	....	.02	.01	....	....
.02	....	....	....	....	....	....	.09	....	.25	.48	2.12	....	....	2.35	....	.21	....	.03	....	....
....	....	T	....	....	....	....	T	....	....	....	.91	.02	....	.77	.02	T	.03	....	....	....
....	....	.15	....	....	T	....	....	.02	....	1.24	.23	....	.01	.14	....	.01	.58	....	....	....
.03	T	T	....	....	....	T	.18	....	....	.01	....	.14	.68	....	....	.02	....	....	....	....
.04	....	....	....	....	.02	....	.58	.01	....	....	T	....	T	....	.02	.22	....	....	....	.01
....	....	....	....	.08	T	....	.86	.01	....	.13	.04	.04	.02	....	.03	.02	.06	....	T	.03
....	....	T	....	....	.22	....	....	.13	....	.41	....	.14	T	.28	....	T	....	....	....	....
....	....	....	....	T	....	....	....	T	.17	.08	....	.04	T	.19	....	T	....	....	....	....
....	....	T	....	.43	....	.04	....	....	.32	.44	....	T	....	....	....	....	T	....	....	....
....	....	....	....	....	....	.05	....	.03	....	....	....	.92	.06	....	.19	.34	....	....	....	....
....	.06	T	....	T	....	....	....	.09	....	....	....	....	.14	....	....	....	.03	....	....	....
....	....	.02	....	....	.12	T	....	.45	....	....	T	.23	....	....	....	....	....	....	....	T
....	....	T	....	....	....	.12	....	....	....	....	.21	....	....	T	....	....	....	....	....	T
T	....	....	....	....	....	.04	T	....	....	1.80	....	2.23	.79	....	....	.03	....	....	T	....
.01	....	.29	....	.02	T	.45	.02	1.11	....	.07	T	.02	T	....	....	.09	....	....	....	....
....	....	.38	....	.11	....	.64	.59	.02	.09	....	T	.04	.03	.07	....	T	T	....	....	....
....	....	....	....	T	....	.05	.03	T	....	T	.12	.12	....	.01	T	.01	....	....	.24	....
....	....	T	....	T	.02	.18	....	.13	.29	....	.12	....	T	....	.03	.05	....	.12	T	....
....	....	T	....	....	....	....	.07	....	.27	T	T	.14	.14	T	.92	T	....	.59	....	....
....	....	T	....	T	.02	T	.03	....	....	.02	....	.02	....	....	.01	....	....	....	....	....
....	....	.01	....	....	T	.11	....	T	....	....	.52	.02	....	1.18	.11	....	....	.03	....	....
....	....	....	....	....	T	.28	....	.04	....	....	....	.10	....	.10	....	.22	....	.86	....	....
....	....	T	....	....	....	T	.03	.28	....	....	....	....	....	.01	.18	....	....	....	....	....
.10	.20	.98	....	.64	.72	2.40	3.95	2.32	2.69	5.07	5.46	6.79	3.17	5.21	2.14	1.57	1.24	2.91	0.24	.77

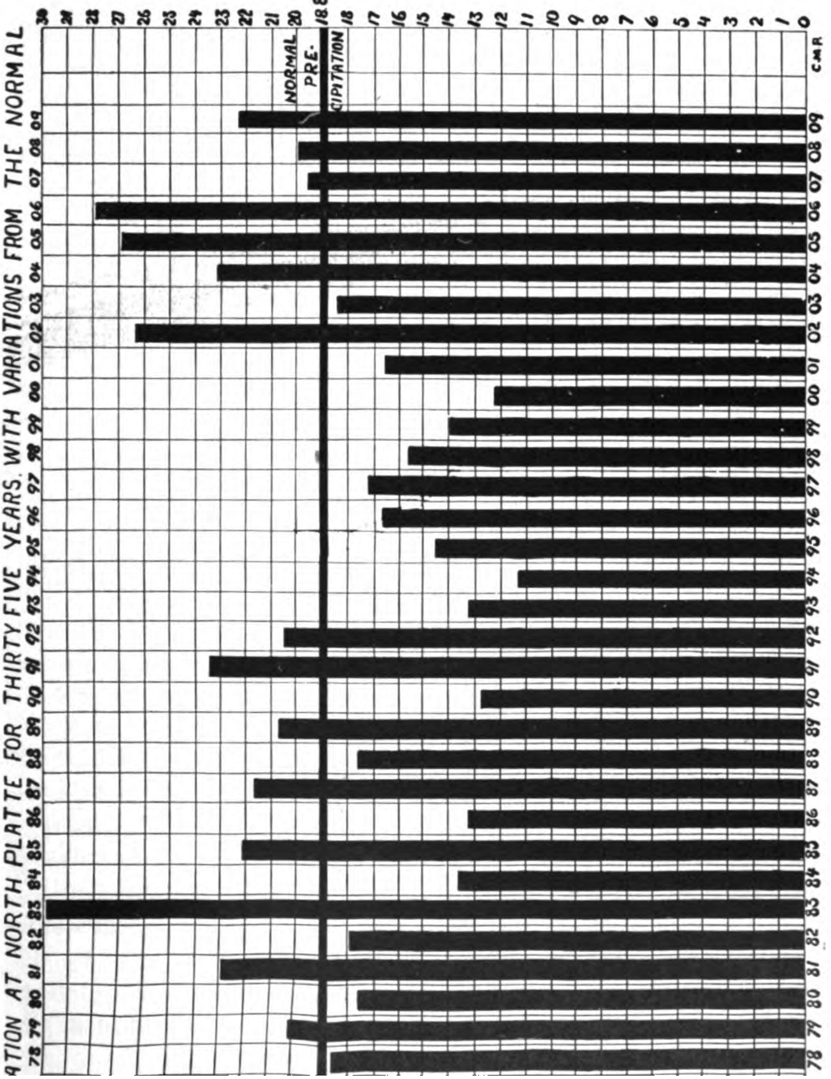
ndicates "trace," less than one one-hundredth of an inch.

LE XXVIII.—*Record of precipitation by months, for thirty-five years, at North Platte, Nebraska.*

Furnished by G. W. McDowell, Observer U. S. Weather Bureau.

Jan.	Febr.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Departure from normal
.24	.26	.40	6.21	1.69	1.62	2.12	.66	1.40	.14	.52	.09	15.35	—3.51
.09	.13	.49	.51	2.97	.49	1.16	2.46	1.47	1.07	.49	.51	11.84	—7.02
1.38	.37	.19	.37	3.22	2.99	2.04	5.03	4.49	1.23	.30	3.86	25.47	+6.61
.00	.18	1.40	1.15	3.24	5.85	3.58	1.52	.91	.13	.46	.20	18.62	— .24
2.33	.43	.11	1.92	2.25	3.31	8.47	.16	.40	.21	.10	.37	20.06	+1.20
.03	.03	.18	.16	2.28	3.12	2.87	3.96	1.53	2.72	.23	.37	17.48	—1.38
.16	.76	1.26	.87	4.84	6.12	3.09	.75	2.36	2.22	.37	.13	22.93	+4.07
.46	.13	.04	1.94	3.98	4.84	2.65	1.68	.28	1.23	.01	.71	17.95	— .91
1.20	1.38	.47	3.02	4.07	7.49	1.34	4.51	1.08	3.47	.42	1.43	29.88	+11.02
.10	.23	1.86	2.14	2.40	1.39	2.19	2.13	.08	.74	.04	.27	13.57	—5.29
.12	.16	.37	1.59	3.31	3.79	3.12	4.87	.86	1.18	1.71	.95	22.03	+3.17
.09	.17	.63	2.09	3.67	1.14	.68	1.99	1.22	.59	.43	.40	13.10	—5.76
.15	.49	.22	3.41	.81	3.20	3.05	4.61	5.10	.15	.19	.30	21.68	+2.82
.09	.42	1.44	2.36	4.93	2.76	2.61	.65	.58	1.12	.08	.42	17.46	—1.40
.97	.07	.62	2.65	2.71	1.95	6.01	2.06	2.57	.31	.20	.54	20.66	+1.80
.35	.38	.27	4.46	.90	2.06	.39	2.42	.19	.84	.42	.03	12.71	—6.15
.65	.49	2.19	2.58	1.69	7.19	3.91	2.45	.87	.57	.08	.69	23.36	+4.50
1.04	.97	.61	4.30	3.70	.60	3.59	3.01	.56	1.49	.08	.42	20.37	+1.57
.03	.62	1.29	.15	1.35	4.11	1.13	3.62	.32	.05	.11	.40	13.16	—5.70
.33	.29	1.72	1.64	.39	3.54	2.39	.17	.14	.59	.01	T	11.21	—7.65
.14	.84	.09	1.93	2.38	4.35	1.08	2.13	.48	.09	.96	.11	14.58	—4.28
.27	.06	.87	3.44	1.47	2.76	1.86	2.07	1.84	1.51	.16	.21	16.52	—2.36
.47	.46	.66	2.59	.11	1.72	1.85	3.05	.59	4.11	.85	.63	17.09	—1.77
.77	.19	.64	1.42	4.12	2.54	1.29	1.40	2.56	.07	.51	.03	15.54	—3.32
.11	.36	.83	.82	3.58	1.95	2.04	1.83	.28	.28	1.59	.32	13.99	—4.87
.06	.78	.26	3.34	.90	1.42	3.37	1.37	.25	.39	.09	.06	12.29	—6.57
.04	.44	1.53	2.53	1.83	3.69	.34	2.00	3.14	.41	.30	.19	16.44	—2.42
.40	.35	1.42	.92	7.98	3.46	4.56	1.74	3.34	1.32	T	.78	26.27	+7.41
.27	1.29	.12	.95	3.74	3.99	2.93	3.58	.76	.44	.28	.01	18.36	— .50
.32	.06	.52	1.52	3.63	4.43	4.90	3.25	2.40	1.92	.03	.19	23.17	+4.31
.90	.69	2.15	3.78	4.56	7.63	2.58	1.57	1.23	1.05	.67	T	26.81	+7.95
.61	.80	2.22	2.89	2.82	.68	3.14	5.56	4.25	3.05	1.01	.96	27.99	+9.13
.39	.51	.10	.43	2.40	2.69	6.79	2.14	2.91	.14	.31	.80	19.61	+ .75
.16	.78	.20	.64	3.95	5.07	3.17	1.57	.24	3.39	.59	.20	19.96	+1.10
.29	1.61	.98	.72	2.32	5.46	5.21	1.24	.77	.20	2.24	1.37	22.41	+3.77
.42	.49	.81	2.04	2.86	3.41	2.90	2.37	1.47	1.10	.46	.49	18.80	

CHART II


ATION AT NORTH PLATTE FOR THIRTY FIVE YEARS, WITH VARIATIONS FROM THE NORMAL
NORMAL PRE-CIPITATION
18.86
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ON THE STRENGTH OF WHEAT FLOUR

BY F. J. ALWAY AND STELLA HARTZELL

The term "strength" as applied to wheat and wheat flour has been so variously defined that it is necessary to state just what is meant wherever it is used. The various definitions have been discussed by Humphries and Biffen[*] and will not be discussed here. We use the term as defined by the Homegrown Wheat Committee of the National Association of British and Irish Millers—"a strong flour is one capable of making large, well-piled loaves; the latter qualification thus excludes flours producing large loaves which do not rise satisfactorily. To estimate the strength of any particular sample of wheat, it is necessary to grind it and make the final tests in the bake house."

Wood[†] pointed out that the two qualities involved in the above definition, namely, size and shape, should be considered separately. He has presented data in support of the explanation which he has offered of the cause of the size of the loaf which a particular flour can make. "The size of the loaf is shown to depend in the first instance on the amount of sugar contained in the flour together with that formed in the dough by diastatic action. It is proposed to measure this by incubating the flour with yeast and water, and collecting the carbon dioxide evolved during 24 hours. Particular attention should be paid to the rate of gas evolution in the later stages of the fermentation, as this is shown to be more directly connected with the size of the loaf."

A preliminary study of the subject of strength of wheat flours begun at this Experiment Station in 1907 was interrupted by the

the study of bleached flour* carried on at this station in 1906-1907. All the samples used except No. 148 were unbleached. No. 148 was used as a standard, it being a fine bread making flour and there being a large amount of it on hand. It had been milled from wheat known to be a good sample of Turkey Red. In the case of many of the flours, the sample remaining after the completion of the bleached flour investigation was too small to permit of baking experiments. In no case, as the original samples had weighed only five pounds each, was there enough flour to permit of more than one baking test.

The evolution of carbon dioxide was determined as follows: Twenty grams of the flour to be tested was placed in a 500 c. c. flask and mixed with half a gram of compressed yeast and 20 c. c. of distilled water. The contents of the flask were thoroly mixed and the flask at once closed with a one-hole rubber stopper, thru which passed a delivery tube connected with a measuring apparatus. The latter consisted of a 500 c. c. narrow-necked flask filled with dilute hydrochloric acid and provided with a two-hole rubber stopper. The delivery tube from the flask containing the flour, yeast and water passed just thru the stopper, while one arm of a right-angle glass tube passed thru the other hole and almost to the bottom of the flask. The horizontal arm of the glass tube was about ten inches long and ended in a tip bent downward. Below the tip a graduated cylinder was placed. As gas was evolved in the first flask it passed into the second, displacing an equal volume of dilute hydrochloric acid, which flowed out into the graduated cylinder. A large water bath kept at 35 degrees C. night and day by means of a thermoregulator was fitted up so that six or seven flasks could be incubated at once. The incubating flasks were changed daily, each being kept in the bath 22 hours. The readings of the volume of gas evolved were made at the end of each hour up to the end of the seventh hour, and the final reading at the end of the twenty-second hour.† The distilled water was heated to 35 degrees before being mixed with the flour and yeast, and the flask was placed in the warm bath immediately after mixing.

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*Bul. 102 of this Station, 1907.

†In a few cases the reading at the end of the seventh hour was omitted.

It is evident from Table I that the yeast varied in fermentative capacity from day to day, the amount of gas evolved during the first hour ranging from 18 c. c. to 54 c. c. The differences in the rate of evolution of gas due to this initial difference in the yeast were less marked in the second hour and disappeared in the third hour.

TABLE I.—*Rate of evolution of gas from flour used as a standard.*

Experiment No.	Date of experiment	Rate of evolution of gas, in c. c., per hour									
		1st hr.	2d hr.	3d hr.	4th hr.	5th hr.	6th hr.	7th hr.	8th to 22d hr.	Total volume of gas evolved, in c.c. — In first 7 hours	Total volume of gas evolved, in c.c. — In 22 hours
1	Aug. 6	29	71	70	59	45	37	39	8	350	459
2	" 6	21	58	73	64	44	40	42	9	342	452
3	" 6	20	68	69	57	45	37	39	9	335	438
4	" 6	22	62	75	60	46	38	38	8	341	448
5	" 6	21	61	78	59	44	43	39	7	345	453
6	" 6	22	62	78	62	46	36	39	8	345	449
7	" 8	50	80	71	47	42	45	45[1]	8	380[1]	465
8	" 8	54	84	70	46	44	38	38[1]	7	374[1]	450
9	" 8	50	85	69	48	42	48	48[1]	6	390[1]	434
10	" 9	32	68	75	36	44	40	38	6	363[1]	447
11	" 9	24	59	74	66	52	43	39	7	357	461
12	" 30	50	76	67	48	28	22	32	8	323	441
13	" 31	37	77	78	58	44	36	43	8	373	507
14	Sept. 2	32	70	63	54	38	20	34	8	311	429
15	" 3	20	51	75	62	48	45	40	8	341	464
16	" 4	18	50	67	55	36	34	29	8	289	410
17	" 5	58	71	67	47	32	27	29	7	331	434
18	" 7	46	70	66	59	43	43	23	7	350	460
19	" 10	10	42	74	54	42	37	38	4	297	356
20	" 11	42	60	69	52	41	30	19	6	313	397
21	" 12	43	74	75	57	48	57	35	5	389	460
22	" 13	50	79	74	60	27	28	56	4	374	435
Av. of 19 expts....		34	67	72	56	42	37	37	7	346	483
Highest of 19 " ...		54	85	78	66	52	57	56	9	389	507
Lowest of 19 " ...		20	51	63	46	27	20	23	4	311	429
Max. difference, per cent.............		170	66	24	43	83	185	144	125	25	18

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[1] The rate of evolution of gas was not observed at the end of the seventh hour. For the sake of uniformity the number for the sixth hour has been repeated, the assumption being that the rate did not decrease.

The results from the same flour are, on the whole, fairly concordant. For samples incubated at the same time, the results are very concordant, as shown both by the first part of Table I and by Nos. 1, 3, 13, 22, 23, and 59 in Table II. Where the readings are unusually low, there may in some cases have been leaks in the apparatus. To guard against this error, two or three samples from the flour being investigated and a corresponding number of samples of the standard flour should be incubated at the same time.

Six or seven samples were incubated at the same time, and on each day except September 25 one of these was a sample of the standard flour. On this date the samples used were Nos. 18, 42, 48, 49, 88, 121, and 140. All of these except the last had previously been tested and the readings on the two dates are concordant. Accordingly it is evident that the conditions on September 25 were normal. In the case of any particular sample the conduct of the standard flour in the same incubation period may be found by comparing the dates of the experiments. On September 10 the amount of gas evolved by the standard was low. During the third hour on this day, part of the flour mixture was forced by the gas from the first flask into the flask containing dilute hydrochloric acid.

TABLE II.—*Rate of evolution of gas from different flours.*

Flour No.	Exp't No.	Mill	Grade of Flour	Date of experiment	Rate of evolution of gas in c.c. per hour								Total volume of gas evolved, in c.c.	
					1st hr.	2d hr.	3d hr.	4th hr.	5th hr.	6th hr.	7th hr.	8th to 22d hr.	In first 7 hours	In 22 hours
1	1	A	Patent	Aug. 8	38	41	36	29	28	32	[1]32	9	236	348
1	2	A	Patent	“ 8	38	43	38	31	29	33	[1]33	9	245	356
2	1	A	Straight	“ 31	64	82	68	42	36	34	38	5	364	434
3	1	A	Bakers'	“ 9	24	59	78	60	53	39	35	7	348	449
3	2	A	Bakers'	“ 9	25	59	75	58	50	41	35	7	343	450
7	1	B	Patent	Aug. 31	2	32	54	42	47	46	47	8	270	386
8	1	B	Straight	“ 31	40	58	53	41	44	42	47	10	325	482
9	1	B	Bakers'	“ 31	20	40	38	26	22	20	23	9	189	323
12	1	C	Patent	Aug. 31	36	66	64	42	36	30	32	7	306	409
13	1	C	Straight	“ 9	18	52	63	49	41	36	31	8	290	404
13	2	C	Straight	“ 9	20	54	63	52	53	48	37	9	327	467
14	1	C	Bakers'	“ 31	36	79	90	68	56	42	43	7	405	516
18	1	D	Patent	Sept. 2	38	62	40	16	10	7	12	2	185	212
	2	D	Patent	“ 25	28	51	43	12	10	9	9	2	162	185
19	1	D	Straight	“ 25	33	64	42	10	6	4	8	2	167	192
20	1	D	Bakers'	“ 25	2	38	54	14	2	1	5	1	116	128
22	1	E	Straight	Aug. 30	54	74	63	26	14	13	20	4	264	327
22	2	E	Straight	“ 30	49	76	67	33	15	12	19	5	271	344
23	1	E	Bakers'	“ 30	47	78	72	35	15	11	15	4	273	329
	2	E	Bakers'	“ 30	45	78	72	37	17	12	17	4	278	341
27	1	F	Patent	Sept. 2	32	65	54	45	36	18	23	10	273	429
28	1	F	Straight	“ 2	37	70	54	34	16	10	14	6	235	324
29	1	F	Bakers'	“ 2	33	70	58	42	22	12	20	6	257	357
30	1	G	Patent	Sept. 3	1	42	66	41	40	40	44	14	274	492
31	1	G	Straight	“ 3	3	32	40	22	22	25	26	10	170	313
32	1	G	Bakers'	“ 3	23	52	84	55	51	40	35	7	340	446
37	1	H	Straight	Sept. 3	14	52	69	40	39	42	38	10	294	444
38	1	H	Bakers'	“ 4	22	48	60	50	29	21	18	4	248	314
42	1	I	Patent	Sept. 4	21	41	46	35	22	23	21	4	209	269
42	2	I	Patent	“ 25	29	58	48	27	26	21	21	3	230	281
43	1	I	Straight	“ 4	23	46	52	41	24	24	21	4	231	288
44	1	I	Bakers'	“ 4	22	46	62	48	26	17	16	5	237	302
48	1	J	Patent	Sept. 25	32	48	35	24	20	16	15	8	190	317
49	1	J	Straight	“ 4	24	40	42	34	25	27	24	8	216	360
49	2	J	Straight	“ 25	32	53	42	27	26	25	24	8	229	355
52	1	K	Patent	Sept. 5	42	60	59	37	34	30	24	7	286	390
53	2	K	Straight	“ 13	51	71	63	44	23	28	30	5	310	392
54	1	K	Bakers'	“ 5	30	77	62	40	23	22	24	4	278	335

[1] See Note. Table I.

TABLE II.—(Concluded.) *Rate of evolution of gas from different flours.*

Flour No.	Exp't No.	Mill	Grade of Flour	Date of experiment	Rate of evolution of gas in c.c. per hour								Total volume of gas evolved, in c.c.	
					1st hr.	2d hr.	3d hr.	4th hr.	5th hr.	6th hr.	7th hr.	8th to 22d hr.	In first 7 hours	In 22 hours
58	1	L	Patent	Sept. 5	41	59	41	33	31	30	29	8	264	392
59	1	L	Straight	Aug. 30	44	72	54	37	27	20	22	9	276	411
59	2	L	Straight	" 30	43	74	59	41	23	17	18	8	275	393
60	1	L	Bakers'	Sept. 5	47	80	59	36	21	18	23	6	284	376
70	1	N	Patent	Sept. 5	44	50	32	25	22	24	27	8	224	315
71	1	N	Straight	" 7	48	55	45	46	39	36	28	8	297	423
72	1	N	Bakers'	" 7	30	57	59	65	53	53	33	7	350	454
7	1	O	Patent	Sept. 7	50	52	41	40	33	37	25	12	278	458
77	1	O	Straight	" 7	50	73	57	51	41	43	31	11	346	516
78	1	O	Bakers'	" 7	52	73	74	79	62	55	35	6	430	520
81	1	P	Patent	Sept. 7	49	66	54	53	43	37	22	8	324	444
82	2	P	Straight	" 10	32	62	76	52	31	23	28	4	304	360
83	3	P	Bakers'	" 10	32	68	92	74	31	22	25	4	344	391
87	1	Q	Patent	Sept. 10	30	48	57	32	15	16	23	3	221	262
88	1	Q	Straight	" 10	31	58	61	20	11	14	19	2	214	226
88	2	Q	Straight	" 25	30	61	51	15	10	10	10	2	187	211
89	1	Q	Bakers'	" 10	31	54	67	46	26	22	28	4	274	339
105	1	R	Patent	Sept. 10	24	49	60	38	31	30	30	6	262	345
106	1	R	Straight	" 11	55	64	62	40	29	23	23	5	296	372
107	1	R	Bakers'	" 11	57	74	88	84	71	23	27	5	424	496
111	1	S	Patent	Sept. 11	52	62	62	50	40	41	27	9	334	494
112	1	S	Straight	" 11	50	54	57	54	42	32	25	11	314	474
113	1	S	Bakers'	" 11	38	55	67	58	56	39	31	12	344	539
120	1	T	Patent	Sept. 11	48	48	45	38	29	37	32	3	277	314
121	1	T	Straight	" 12	35	58	53	32	23	21	74	1	236	245
121	2	T	Straight	" 25	31	56	53	29	20	14	13	2	216	243
122	1	T	Bakers'	" 12	39	66	59	28	17	24	19	1	252	269
123	1	U	Patent	Sept. 12	38	62	59	43	36	34	25	5	297	368
124	1	U	Straight	" 12	38	66	63	43	36	34	25	5	305	379
125	1	U	Bakers'	" 12	37	66	77	54	39	36	25	4	334	393
130	1	V	Patent	Sept. 12	33	62	68	45	42	49	44	10	343	488
131	1	V	Straight	" 13	1	66	63	35	16	17	25	4	223	284
132	1	V	Bakers'	" 13	54	79	83	66	42	36	47	5	407	501
139	1	X	Patent	Sept. 13	53	70	71	57	42	44	47	9	384	516
140	1	X	Straight	" 25	16	57	80	43	43	34		17	273	483
141	1	X	Bakers'	" 13	54	78	81	63	43	45	52	5	416	496

There is in general a marked similarity in the conduct of the different flours from the same mill. An example of this is afforded by those from mills D and T, where there was an almost complete cessation in the evolution of gas after the sixth hour.

There is less variation among the different flours examined than Wood found among the eight which he reported. This is probably due to the fact that our samples were all from the same State and also almost entirely from the same variety of wheat, Turkey Red, while those of Wood differed from one another in variety and also, probably, in geographical origin.

The data from the baking experiments are given in Tables III and IV. The "sponge," or long, fermentation process was employed. The gas oven used was large enough to bake only four loaves at a time: hence each baking was limited to four loaves, one from each of four samples of flour, of which the standard was one. On October 10 the standard flour was omitted. For each loaf the fourth of a cake of compressed yeast, 2.5 grams of salt, and 130 c. c. of water were used, while the amount of flour varied slightly from the amount desired, namely, 200 grams. A quantity of the flour was weighed out before beginning the experiment and the portion remaining after the making of the dough was weighed. The difference gave the amount used for the loaf. The cake of yeast was mixed thoroly with 40 c. c. of water at 35 degrees C., and one-fourth of this was used for each loaf. The salt was dissolved in 120 c. c. of water, also at 35 degrees C., and the flour stirred in to make the batter. This batter was allowed to ferment from two to three hours in a cupboard kept at 35 degrees C., then mixed with more flour and the dough kneeded until smooth. The dough was then returned to the cupboard kept at 35 degrees C., and allowed to rise until it had doubled its bulk. Then it was baked. The time which elapsed between the mixing

TABLE III.—*Baking tests of flour used as a standard.*

Date of baking	Weight of loaf	Volume of loaf	Weight of flour used	Volume of loaf per 100 grams flour	Volume of loaf from 100 grams flour Av =100
	Grams	c c.	*Grams*	c.c.	
Sept. 5.....	277	671	180	372	110
Sept. 7	260	667	203	329	97
Sept. 9.....	264	675	198	341	101
Sept. 11....	257	633	198	320	94
Sept. 13....	260	685	199	344	101
Sept. 26....	259	704	200	352	104
Oct. 4	269	680	203	335	99
Oct. 7 ..	280	686	198	346	102
Oct. 8 .	284	659	211	312	92
Average .	268	673	199	339	100

TABLE IV.—*Baking tests.*

Flour No.	Date of baking	Wt. of loaf	Vol. of loaf	Wt. of flour used	Vol. of loaf per 100 grams flour	Vol. of standard per 100 grams flour	Relative vol. of loaf per 100 gr. flour. Standard = 100	Evolution of gas compared with standard		
								In 22 hrs	In first 7 hrs.	In 5th, 6th and 7th hrs.
		Grams	c.c.	*Grams*	c.c.	c.c.				
1	Sept. 9	260	755	211	358	341	105	71	63	72
2	" 9	264	706	210	336	341	99	76	98	88
3	" 9	260	681	201	339	341	99	101	94	103
7	" 13	256	650	201	323	344	94	76	72	114
8	" 13	261	646	214	302	344	88	95	87	109
14	" 26	255	623	191	326	352	93	102	109	115
19	" 26	255	648	202	321	352	91	....	....	......
22	" 5	281	674	213	316	372	85	76	83	51
23	" 5	281	704	212	332	372	89	76	85	50
27	" 5	286	670	225	298	372	80	100	88	84
28	" 7	260	666	203	328	329	100	76	76	43
29	" 7	258	692	207	334	329	102	83	83	59
30	" 7	264	769	218	353	329	107	106	80	93
31	Oct. 8	284	697	214	326	312	105	68	50	55
37	Sept. 13	253	792	202	392	344	114	96	86	89
52	Oct. 8	275	673	202	333	312	107	90	86	100
58	" 8	267	665	196	339	312	109	90	80	102
71	" 4	267	724	204	355	335	106	92	85	94
78	" 4	280	690	198	348	335	104	113	123	139
82	" 10	271	752	202	372	339[1]	110	101	102	70
88	" 4	268	593	194	305	335	97	63	72	38
105	" 7	280	715	203	352	346	102	97	88	78
107	" 7	276	562	195	288	346	83	125	136	134
121	" 7	274	776	206	372	346	108	53	60	43
131	" 10	258	664	187	355	339[1]	105	65	60	52
139	" 10	264	648	192	337	339[1]	100	119	99	120
141	" 10	269	683	196	348	339[1]	103	114	111	128

[1] Compared with the average, no bread from standard flour being baked on this day.

The size of the loaf (= volume per 100 grams of flour) varied in the case of the standard flour from 8 per cent below to 10 per cent above that of the average of the nine bakings. The size of the loaf obtained from the standard flour in each baking test is given in Table IV, seventh column. The eighth column gives the size of the loaf obtained from each flour compared with that obtained from the standard flour on the same day (=100). The last three columns show the relative amounts of gas evolved in the incubation experiments (Tables I and II) compared with the amounts evolved by the standard flour in the same incubation experiment.

In Table V, in order to show the relation between the size of loaf and the amount of gas evolved in the whole 22 hours, in the first 7 hours, and in the last stages of the bread making, 5th, 6th, and 7th hours, the flours are arranged in the order of the size of the loaves produced.

TABLE V.—*Relation between volume of loaf and evolution of gas. Standard=100.*

Flour No.	Vol. of loaf per 100 gr. flour	Evolution of gas		
		In 22 hours	In 7 hours	In 5th, 6th and 7th hours
37	114	96	86	89
82	110	101	102	70
58	109	90	80	102
121	108	53	60	43
30	107	106	80	93
52	107	90	86	100
71	106	92	85	94
1	105	71	63	72
31	105	68	50	55
131	105	65	58	52
78	104	113	123	139
141	103	114	107	128
29	102	83	83	59
105	102	97	88	78
28	100	76	76	43
139	100	119	99	120
2	99	76	98	88
3	99	101	94	103
7	94	76	72	114
14	93	102	109	115
88	91	63	68	38
23	89	76	85	50
8	88	95	87	109
22	85	76	83	51
107	83	125	136	134
27	80	100	88	84
Av. of first 13	106.5	87.8	81.8	84.3
Av. of last 13	92.5	91.0	91.0	86.7

There is clearly no direct connection shown between the size of the loaf and the volume of gas evolved. The thirteen flours which gave the largest loaves evolved on the average somewhat less gas than the other thirteen flours.

Allowing for all experimental errors, it seems at least improbable in view of the above that there is any marked connection, in the case of somewhat similar flours, between the size of loaf and the amount of gas evolved in incubation experiments. While we do not wish to imply that there are not valuable results to be derived from an exhaustive study along the lines of Wood's conclusion, any such study requires, in addition to the ordinary laboratory equipment, a skillful baker and a large oven.

Most commercial flour-testing laboratories work on a small laboratory scale and in the case of flours from the same variety of wheat the results obtained are often of very doubtful value.

HISTORY OF HOG CHOLERA EXPERIMENTS IN NEBRASKA

By A. T. Peters.*

During the years 1899 to 1903, experiments were conducted at this Station with hog cholera to ascertain whether a method of vaccination could be devised that would at least prevent and if possible cure hog cholera. The work of 1896, 1897, and 1898 has been reported in the Thirteenth Annual Report and in Bulletin No. 47. The experiments that were of importance were those for making hog cholera serum by the use of horse serum,—described in Bulletin No. 47.

Table I.—*Hogs treated with horse hog cholera serum.*

Year in which outbreak occurred	No of out-breaks	No. of hogs treated	No. of hogs sick at the time of treatment	No. of hogs not sick at the time of treatment	No. of hogs saved from sick lot	No. of hogs saved from well lot	Total number of hogs saved
1899	45	3,692	2,164	1,528	872	1,110	1,982 or 53%
1900	39	3,243	1,810	2,432	946	1,760	2,706 or 83%
1901	54	4,109	2,894	1,215	1,272	909	2,181 or 53%
1902	31	2,964	1,842	1,122	639	888	1,527 or 51%
1903	38	3,046	1,966	1,080	334	979	1,313 or 43%

Table I shows the number of hogs treated in each year and the number saved. It is of interest to note that in the year 1900, when by far the larger number of hogs treated were well at the time of treatment, a very creditable showing was made for hog cholera serum. All other years show that by far the larger number of hogs treated were sick when treated, and the per cent saved was not satisfactory. After the year 1903, in which we made such a poor showing, the work with horse serum was suspended. During all these years we seldom used more than 10 tant thing should be remembered, and that is that the hog cholera serum, whether it had much protective power or not, showed that it had very little if any curative power on sick herds. One important thing should be remembered, and that is that hog cholera serum was used in a large measure on very sick hogs and in the larger per cent of cases after the disease had been in progress for from three to five or more days. In most of the outbreaks a careful post-mortem examination was held to ascertain if the disease was really hog cholera. The important points noted were, whether the kidneys had petechiae, whether the intestinal tract had ulcers, the condition of the glands, and the size and condition of the spleen. If these characteristic lesions were present it was considered beyond a doubt a true case of hog cholera. In only about 35 per cent of the cases were bacteriological examinations possible in addition to the post-mortem.

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*Resigned January 1, 1910.

Laboratory Work.—Experiments were conducted in the laboratory on the growth and characteristics of hog cholera bacilli. It was hoped that the investigations would reveal some important facts regarding the variation of the hog cholera cultures, for it was well known that a bullion culture would be very destructive in one herd and the same culture would not have any effect on another herd even when used the same day. Operators in the field attributed this variation to the difference in the feeding or susceptibility of the animals. For this reason hog cholera cultures were grown on horse blood serum and hog blood serum to see if the media would have any influence on the germ itself and if these blood media would increase its virulence. Experiments were conducted as follows: Forty-eight-hour hog cholera cultures were grown at room temperature on horse and hog serum. To these tubes was added a normal sterilized salt solution and the germs washed off the media. Five c.c. of this hog cholera salt solution were injected into three hogs with the following results:

All three hogs injected with the serum from the hog serum died 10, 14, and 16 days after the injection. Of the hog cholera serum of the horse blood, only one of the three injected died. This method showed no advantages over the method of cultivating hog cholera germs in bullion.

The standard used in the laboratory to ascertain if a germ was really that of hog cholera was that adopted by the Government in Bulletin No. 3 of the Bureau of Animal Industry, U. S. Department of Agriculture. All hog cholera germs had to conform to these laboratory characteristics. It had to stain readily with Loefler's Alkaline Blue and had to show under proper stain the characteristic flagella.

The difference between the hog cholera germ and the swine plague germ was never carefully studied by the writer. He will admit that the swine plague germ has entirely different laboratory characteristics and cannot be mistaken when seen under the microscope, but he does not consider that the swine plague germ is in any way serious in producing swine diseases and that, while it is an associate and can be found in most animals affected with hog cholera, it no doubt can be classed the same as the *colli bacilli,* which is almost always found in a case of typhoid and yet does not produce typhoid fever.

POST-MORTEM.—In a post-mortem the writer would not consider it essential that, when the lungs are affected and the intestines are practically free other than showing slight hemorrhagic infection, this form should be termed swine plague. Any bacteriological examination held on animals so affected revealed the hog cholera germ as well as the swine plague germ. The writer does not believe that symptoms are a very safe guide for the positive diagnosis of hog cholera, but that a post-mortem examination is the surest method of determining hog cholera. The following lesions should be a guidance: the glands are very much inflamed, the intestinal tract shows the ulcerations and the hemorrhagic infarction, the kidneys are studded with these same blood spots, the spleen is very much enlarged, and the lungs more or less solidified.

In 1903 Dr. Dorset of the Bureau of Animal Industry, United

States Department of Agriculture, discovered that the blood of hogs affected with hog cholera when filtered was still capable of producing the same disease. This brought about an entirely new situation in the hog cholera experiments. Up to this time all the experimenters were using the germs of hog cholera and of swine plague, relying on these as the sole cause of the disease. When it was found that the blood of diseased hogs showing the germs prior to filtration and free of germs after filtration was still capable of producing the disease, new methods for making vaccine had to be employed, and so Dr. Dorset used for the first time the entire blood of a hog that had the disease and injected this in large amounts into a hog that either had recovered from hog cholera or had been previously vaccinated and thereby made these hogs what is known as hyperimmune. The blood of these hyperimmunes when defibrinated and used on healthy hogs produces a limited immunity. If used with diseased blood it gives practically a permanent immunity.

Laboratory work to ascertain the virulence of filtered diseased hog blood was started in May, 1904. For this experiment three hogs were used and the results are shown in Table II. It proved conclusively that the filtered blood was capable of producing the disease.

TABLE II.—*Experiments in 1904 with filtered blood according to the Dorset method.*

Tag No.	Date 1904	Defibrinated blood	Date when taken sick	Date of death	Post-mortem
201	May 6	5 c.c. defibrinated filtered blood of Allen outbreak.	May 14	May 18	Ulcers; very advanced case.

IMMUNITY OF HOGS RECOVERED FROM CHOLERA.

In 1898, 1899, and 1900, experiments were conducted to make hyperimmune hogs and to use the serum in the field, which was done with gratifying results. Much had been said about hogs that had recovered from hog cholera in a natural way being immune and that they could farrow in diseased pens and not lose their offspring. Experiments were conducted to ascertain if this is true. For this purpose hogs that had recovered from hog cholera were purchased and placed in the hog cholera pens and there exposed in various ways. Table III will show that these hogs and their litter were immune against hog cholera, which is an important fact to know. It will be noticed that these hogs in Table III were all exposed to dead hogs and that post-mortem and bacteriological examination revealed unquestionable hog cholera, and the results of these exposures show that they had perfect immunity.

TABLE III.—*Hogs purchased from farmers over the state after recovery from a natural infection of hog cholera.*

Tag No.	Recovered from hog cholera.	Farrowed	Exposed	Results of exposure
52	February, 1898, white sow.	6 pigs July 4.	July 8, dead hog placed in pen.	All pigs remained well. One check placed in pen took sick 8 days after and died the third day.
54	February, 1898, Poland China sow.	5 pigs July 12.	July 16, exposed in a herd at Raymond.	This was a severe outbreak. Out of 110 animals in herd all but 21 died. None of the exposed animals died or took sick. Post-mortem and cultures showed hog cholera bacilli.
55	January, 1898, grade sow.	9 pigs July 1. Lost 6 before exposure.	July 6, dead hog was placed in pen.	All remained well. Check died ten days after exposure.
56	March, 1899, white sow.	5 pigs July 28.	Aug. 3, placed in pen with sick hogs.	Animals showed no signs of sickness. No check in this lot.
57	February, 1899, white sow.	4 pigs July 15.	Sow and litter sent to Malcolm and placed in hog cholera outbreak.	This was a very severe outbreak. Out of 163 only 42 recovered. Sow and pigs not sick at all. Post-mortem and cultures showed hog cholera bacilli.
58	April, 1899, white sow.	6 pigs Aug. 7.	Exposed by placing in hog cholera pen Aug. 12.	Animals remained well. Small check placed with these animals took sick 8 days after exposure but recovered.
61	March, 1899, white sow.	5 pigs Aug. 15.	Exposed to hog cholera Aug. 21 by placing dead hog in pen.	Animals remained well. No check placed in this pen.

In the year 1899 we purchased a large number of sows which were immune by natural cholera or vaccination. They farrowed litters in the spring and summer of 1900. About three weeks previous to farrowing they were immunized by vaccination or feeding virus and the sows and the litters were later sent out and placed in cholera herds as follows:

Lot No. 169 was a sow and six little pigs, placed Sept. 24 with 74 sick hogs belonging to Mr. W. S. of Davey, Nebr. Sow and litter did not take disease in sick herd.

Lot No. 161 consisted of two weanlings shipped per express Sept. 14 to Mr. W. D. H. of Wayne, Nebr. No report of results.

Lot No. 156 was a sow and 8 little pigs placed Aug. 31 with 47 sick hogs belonging to Mr. S. M. of Saltillo, Nebr. Sow and litter did not sicken in cholera herds.

Lot No. 145 was a sow and 6 little pigs taken Aug. 29 to Mr. J. W. L. of Walton, Nebr., and placed with his 73 head of sick hogs. He lost all but 7. Sow and pigs did not sicken.

Lot No. 137 consisted of two weanling pigs, shipped Aug. 16 to Mr. J. S. A. of Seward, Nebr. They were placed in four cholera herds in succession without sickening.

Lot No. 33, two weanling pigs, was shipped July 3 to J. W. G. of Wymore, Nebr., who placed them in several severe outbreaks without their taking cholera.

Lot No. 25, a sow and six pigs eight days old, was taken on June 29 to J. R. of Cheney, Nebr., and placed with his 46 head of sick hogs and they ate, drank and slept with his until all of his were dead but 4. These pigs were then placed in other cholera herds without sickening.

Lot No. 17, a sow and 7 little pigs, on May 2 were placed in a sick cholera herd of about 315 hogs, all ages, belonging to Mr. G. E. of West Lincoln, Nebr. They remained in the pens with his until all but 26 of his died and our pigs were well and fat when they were removed at 7 weeks old and put in another herd of sick cholera hogs.

Lot No. 171, two little pigs, was shipped per express Sept. 29, to Mr. H. D. of Leigh, Nebr., to place in his cholera herd. They were healthy on Oct. 26.

Lot No. 159, two weanling pigs, was shipped per express Aug. 20, to Messers. L. & W. of Lyons, Nebr., and they moved them from one sick herd to another and wrote that the pigs were O.K.

In addition to this, Table IV shows sows not immune by natural cholera that were vaccinated and then several weeks before farrowing were fed or injected subcutaneously with hog cholera culture. It will be noted that some of the sows died from the vaccination, which consisted in giving them the serum and culture at the same time, and which is known as the Lawrence Method and is described in detail in the Thirteenth Annual Report.

E IV.—*Hogs previously vaccinated with 20 c.c. of horse cholera serum and 2 c.c. of virus ıd then treated 3 weeks before farrowing by vaccinating or feeding cholera virus.*

of ıla- n	Date when taken sick	No. of days between inoculation and sickness	Date of death	Date of vaccination	.5 c.c. of virus	Date of farrowing	No. of pigs and their condition
5 3	May 16	11	May 21				
5 8	May 21	18	Recovered				
5 8	May 14	9	Recovered				
5 8	May 12	7	May 19				
5 8				June 8	Injected subcutaneously	June 24	6 pigs very bad condition
7 3				June 8	Injected subcutaneously	June 27	7 pigs in good condition
7 8				June 3	Injected subcutaneously	June 11	6 pigs not in good condition
12 8				June 8	Fed in milk	June 26	8 pigs in good condition
12 98				June 3	Fed in milk	June 14	5 pigs alive and 2 dead

TABLE V.—*Hogs that recovered from cholera and were treated three weeks before farrowing.*

Sow No.	Date 1898	Record	Date of farrowing	No. of pigs and their condition	Remarks
80	Sept. 10	Fed on hog cholera carcass	Oct. 3	5 pigs in fair condition	On Oct. 21 this sow and litter was sent to Shelby, Nebr., and placed on four farms. All lived while 9 out of 14 checks died.
83	Sept. 10	Fed on hog cholera carcass	Oct. 6	7 pigs in good condition	On Oct. 26 this sow and litter was sent to Brainard, Nebr., and exposed to hog cholera. All lived. No record kept of the checks.
84	Sept. 10	Fed hog cholera culture in swill	Sept. 30	8 pigs in good condition	On Nov. 3 this sow and 6 pigs (all that lived) were placed in four outbreaks. Eleven out of 16 checks died.
87	Sept. 10	Injected subcutaneously 5c.c.	Oct. 5	6 pigs stunted in growth	On Oct. 10 this sow and 5 pigs (all that lived) were placed in the experimental pens and dead hogs fed to them. On Nov. 18 the sow was sent to the Animal Husbandry Department and the pigs (Nos. 92, 93, 94, 95, and 96) were kept for further experiments.

It was suggested that it would be interesting to know the duration of immunity of these litters. Litter of sow No. 87 was exposed to dead hogs and some of them injected with hog cholera culture and the results show that this litter after five months was not immune to hog cholera. The same is true of the litters of sows Nos. 39, 43, 60, 64, and 67. In the litter of sow No. 60 only one died, showing that this hog had not acquired sufficient immunity. The litters of sows No. 67 and No. 60 were the only ones where losses occurred, showing that they did not have thoro immunity. It is regretted that more work along this line was not done. It is one of the most important lines of hog cholera research before the investigator.

TABLE VI.—*Experiment to test the length of immunity of hogs naturally infected.*

EXPOSURE OF LITTERS NOS. 52, 56, AND 58 OF TABLE III.

Tag No.	Date of farrowing. Year 1900.	Date of exposure	Remarks.
52	6 pigs farrowed July 4.	Dec. 1.	In hog cholera pen with a number of sick animals. All sick Dec. 10, of which 3 recovered. One check placed in pens took sick Dec. 6 and died Dec. 9.
56	5 pigs farrowed July 28.	Dec. 11.	This litter was placed in the quarantine pens, and fed 10 c.c. of hog cholera culture in half a gallon of sour milk. Two checks placed in the pens took sick Dec. 17 and died on the 19th and 21st. Two of the litter took sick on the 19th but recovered. Post-mortem and cultures showed hog cholera bacilli.
58	6 pigs farrowed Aug. 7.	Jan. 3.	Exposed in quarantine pens and check animals placed with them Jan. 9. All animals including checks sick on Jan. 12. Two of the litter and one check dead. The other check died on Jan. 15. Two of the litter were killed on Jan. 20 on account of being so poor. The others recovered Feb. 2. Post-mortem and cultures showed hog cholera bacilli.

RECORD OF LITTER OF SOW NO. 67, OF TABLE IV, EXPOSED TO HOG CHOLERA.

Date 1900	

TABLE VI.—(Continued)—*Experiment to test the length of immunity of hogs naturally infected.*

RECORD OF SOW NO. 87 AND LITTER.

These five pigs were the litter of hog No. 87, Table IV.

Tag No.	Date 1900	Culture virus	Date when taken sick	Number of days after inoculation	Date of death	Remarks
92	Feb. 1	5 c.c.	Feb. 9	8	Feb. 13	The check hogs that were in the pen all died.
96	Feb. 1	5 c.c.	Feb. 14	13	Feb. 18	
94	Feb. 6	Exposed in hog cholera pen with two checks not treated.	Feb. 20	14	Mar. 8	
95	Feb. 6		Feb. 20	14	Mar. 11	
93	Feb. 6		Feb. 20	14	Mar. 13	

RECORD OF THE LITTER OF SOW NO. 39 OF TABLE IV, EXPOSED TO HOG CHOLERA.

Date 1900	
July 14	This sow and litter was sent to Mr. M. at Stromsburg and placed in hog cholera pens. It was placed on three farms without losing any of the pigs. All check pigs placed with them died.

TABLE VI —(Continued).—*Experiment to test the length of immunity of hogs naturally infected.*

RECORD OF THE LITTER OF SOW NO. 43 OF TABLE IV, EXPOSED TO HOG CHOLERA.

Date 1900	Poland China sow farrowed 6 pigs June 11.
June 18	Fed carcass of hog No. 92 which was very badly affected with hog cholera.
June 23	3 small check pigs from a sow not treated—Nos. 17, 18, and 19 were added to this pen.
June 27	Nos. 17 and 18 off feed—scouring.
June 30	No. 19 sick.
July 1	Nos. 17 and 18 found dead in pen.
July 3	No. 19—did not think he would live until morning so was killed for post-mortem.
July 30	Sow and litter, still well, were sent to Animal Husbandry Department. Litter seemed stunted in growth but were never sick with cholera.

RECORD OF THE LITTER OF SOW NO. 60 OF TABLE IV, EXPOSED TO HOG CHOLERA.

July 1	Fed carcass of No. 17 to sow and litter.
July 7	One little pig (the smallest in the litter) sick.
July 9	Sick pig dead.
July 30	Sow and litter taken to Department of Animal Husbandry.

RECORD OF THE LITTER OF SOW NO. 64 OF TABLE IV, EXPOSED TO HOG CHOLERA.

Date 1900	
July 1	Fed pig No. 18. Post-mortem showed advanced hog cholera lesions.
July 2	Pigs Nos. 21 and 22 placed in pen as checks—not treated.
July 9	Both pigs sick and off feed.
July 11	No. 21 dead.
July 12	No. 22 dead.

TRANSPIRATION EXPERIMENTS WITH THE CORN PLANT

(Preliminary Report.)

BY T. A. KIESSELBACH.

When we make a study of the conditions prevailing in years of general crop failure or crop shortage in regions that are normally very productive, it is found that the cause can usually be ascribed to a lack of water available to the plants. This is not at all strange, for the leaves of plants in a dense vegetation act as a great pump, drawing water from the soil at a tremendous rate. An average corn plant in eastern Nebraska has a leaf area of about 1200 square inches. This means that with the normal rate of planting in hills three feet six inches apart and three plants in a hill, the leaf area of corn plants on one acre of land is twice the area of the land. In other words, each acre of corn has two acres of leaves.

It was found at the Nebraska Experiment Station that a single plant with 1250 square inches leaf area lost nine pounds of water during 8½ hours of August 9, 1909. Charging this much transpiration to each corn plant in an acre having a full stand as above indicated, forty-eight tons of water were transpired by the plants of a single acre during 8½ hours of that day. This is nearly ½ acre-inch of water, and if it were spread evenly over the surface of all the leaves it would form a layer nearly ¼ inch deep.

As the experiments herein reported will indicate, water that is drawn up from the soil is lost from these leaves much as water is lost from a sponge when exposed to a drying atmosphere. The rate of this water loss in a given plant depends chiefly upon cli-

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*These experiments were conducted as graduate work in the Department of Experimental Agronomy. Acknowledgment is made to Professor E. G. Montgomery for helpful suggestions and generous aid in obtaining the necessary materials.

matic conditions. If the atmospheric demand for moisture continues and the plants are unable to absorb moisture at the required rate, the plant tissues collapse and ultimately die from drouth.

Where an abundance of water is available, corn plants are fully able to absorb all necessary water under the most drying field conditions such as hot, dry winds..

The noticeable relation of water supply to plant growth has led to numerous inquiries and investigations to find if possible some practical means for reducing the amount of water that the plant must absorb for normal growth. It is with this same object in view that the following experiments were undertaken by the writer in a preliminary way. Such a search involves a study of the functioning of the plant itself, and the method used must be such as to permit an accurate determination of the absolute transpiration by the plant, or that quantity of water which is evaporated from the leaves and stems. In order to study the effect of variations in any one particular environic factor, all of the plants should be subjected to otherwise identical conditions. Differences in results may then be quite safely ascribed to corresponding differences in the one factor under control. Several such factors may be combined in order to study variations with several factors under control.

Many results obtained in the past have been accounted for by the apparently erroneous supposition that the leaf stomata or breathing pores exert a regulatory control over the quantity of water transpired according to variations in the conditions of growth. That there is no such regulatory control was pointed out in experiments by Lloyd in which he determined the absolute transpiration from plant cuttings. A similar negative result was obtained by the writer with growing rooted corn plants from which the absolute transpiration was determined under the following conditions.

Altogether, observations were made with 40 corn plants of an early yellow dent variety. Twenty of these were grown for 64 days in rich alfalfa sod loam soil watered with well water, while the other 20 were grown for 76 days in sand watered with a complete nutrient solution. Those plants grown in soil have been called the Soil Saturation Series because they were divided into 5 sets of 4 plants each, each set of which was kept at a different degree of saturation.

The plants growing in the sand were kept at an almost constant saturation of 100 per cent. They have been called the Soil Fertility Series because they were divided into 4 sets of 5 plants each, each set having a different strength of solution added.

The object in view with the soil saturation series was to find if possible the relation, if any, between transpiration and the water content of the soil. It has commonly been held that the total amount of water transpired and the quantity used per gram dry matter produced were in more or less direct relation with the soil water content. In this connection the plants in the soil sat-

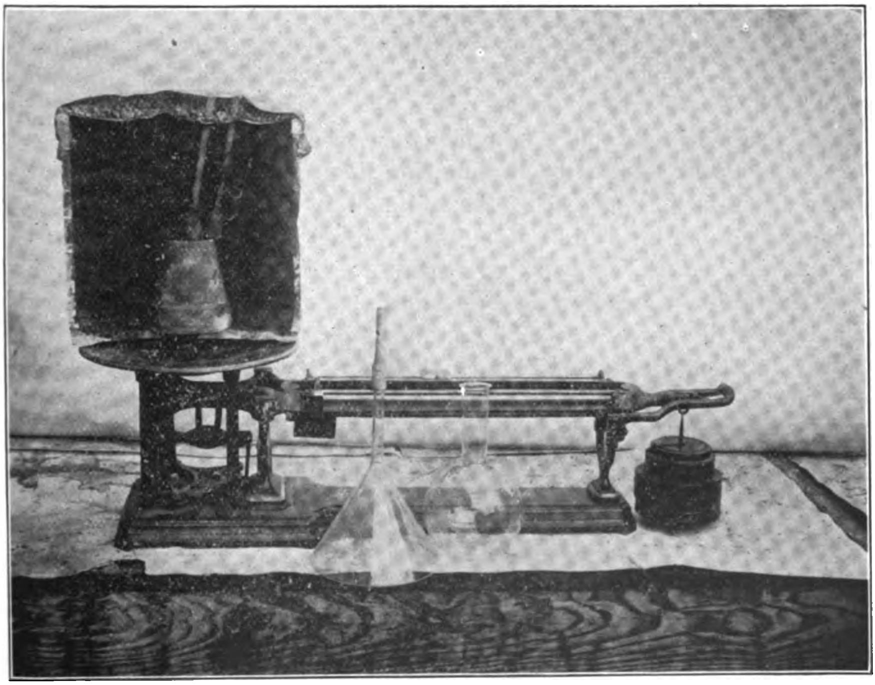


Fig. 1. Construction of apparatus as used. Vertical section.

uration series were studied in regard to the relation of soil water content to changes in the quantity of water transpired as influenced by changing climatic factors.

The soil fertility series was intended to throw light upon the relation of soil fertility to the quantity of water transpired in producing a given dry weight. It has been quite commonly believed that the quantity of water transpired per gram dry weight increased considerably as the strength of solution decreased.

To make these determinations a new apparatus which may be termed a transpirometer was devised.

Into the bottom of a 4-gallon glazed stone jar was placed an empty inverted 4-inch porous flowerpot. This pot was connected with the surface of the jar by means of two ¼-inch glass tubes and served both as a water chamber and an aerating device. One-half liter of water could be added at a time thru one tube by means of a funnel with rubber tubing connection and the displaced air escaped thru the other tube. The jar was nearly filled with air-dry soil, which was firmly packed about the inverted flowerpot. The water added in the pot was quickly absorbed by the surrounding soil mass until saturated. By knowing the weight of the apparatus and the total dry weight of the soil contained, and the weight of water required to saturate it, any desired percentage of soil saturation could be maintained by frequent weighings and replacement of the water transpired by the plant. Surface evaporation was prevented by three sheets of paraffined parchment paper, lapped over and tied firmly to the jar. A layer of gravel about an inch in depth was placed upon the paraffined paper, both to weigh it down and to prevent evaporation thru the 1½ inch space about the corn plant. The plants were grown out of doors in a cornfield. The entrance of rain was guarded against by permanent closely fitting oilcloth covers and a temporary canvas tent covering during all rain storms.

The type of transpirometer used in these experiments has the following characters:

1. The roots penetrate thoroly thruout the soil mass.
2. The absolute transpiration may be definitely determined.

3. Thoro aeration of the soil is permitted.

4. The plant may be grown normally in a soil or sand culture medium for a great length of time.

5. The addition of water is easily accomplished, and constant soil saturations may be maintained by weighings.

SOIL SATURATION SERIES

Each transpirometer contained 15,680 grams of air-dry soil. It required 6,099 grams water to saturate the air-dry soil which contained 8½ per cent hygroscopic moisture.

Five degrees of soil saturation were maintained, based on the air-dry soil, viz., 98, 80, 60, 40, 20 per cent saturation with 5 to 10 per cent variation. Each transpirometer was weighed separately in grams every 48 hours at 7 P. M. Water was added several times during each interval so as to avoid much variation from the desired percentage. The saturation never was greater than the assigned degree, and each 48 hours the exact weight was restored. At the age of six weeks, 200 grams of water were added to the total weight, to partially balance the increased weight of plant.

One corn plant was grown in the center of each transpirometer. The seed was planted July 3 and harvested September 5, 1907. As the quantity of soil was not sufficient to grow the plants to maturity they were harvested green, shortly after the silking stage.

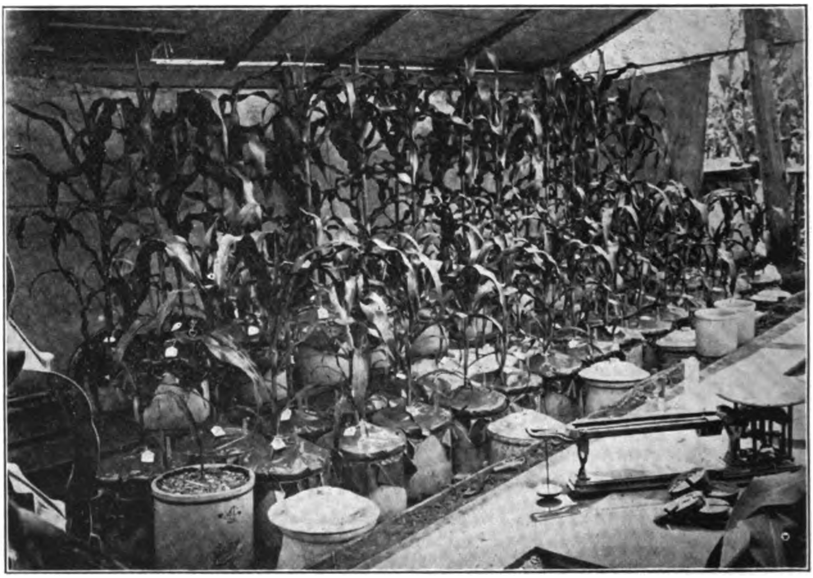


Fig. 2. These plants were regularly located on the same level on either side of the trench, but for the purpose of taking this picture the plants in the soil fertility series have been placed in the trench. Note the great uniformity of the growth of plants in each series. The canvas background was temporary for taking the picture. Photo taken August 13, 1908.

The retarded growth of plants in the 20 per cent soil saturation (Table I) indicates that in this soil and under these conditions of growth the water supply was deficient. Of all the plants, these alone wilted somewhat when conditions were conducive to heavy transpiration.

Regardless of the soil water content, the total amount of water used in all cases was very uniform, except in the 20 per cent saturation where it was considerably less. This falling off may doubtless be accounted for by the rather frequent wilting of the leaves.

Nearly the same amount of water was transpired per gram

TABLE I.—*Showing correlated results.*

(Corn planted July 3 and harvested Sept. 5.)

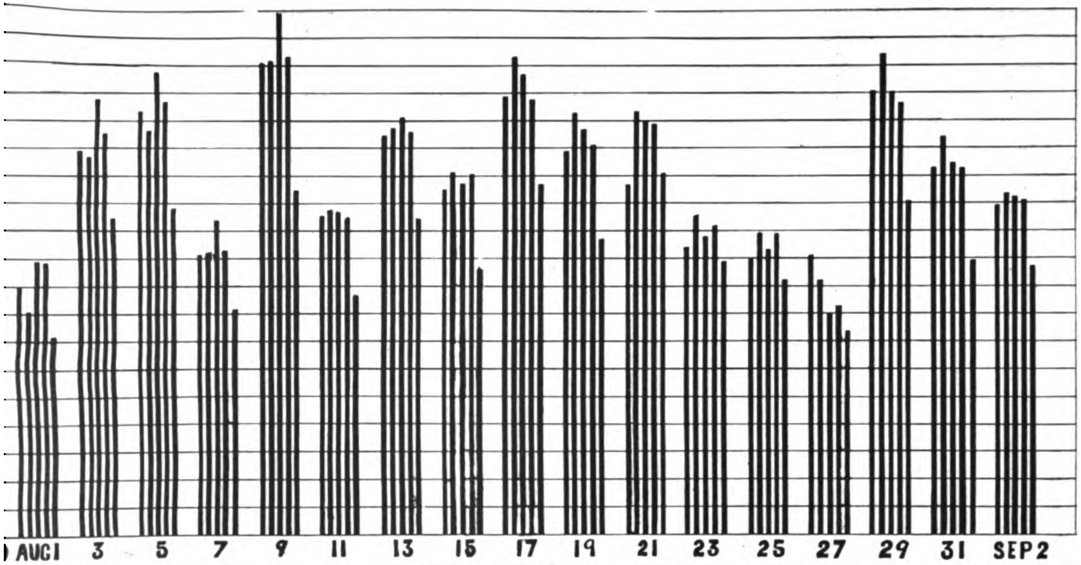
No. plants averaged	Saturation maintained (5-10 per cent variation)	*Average leaf area Sept. 2	Water used per plant	Water used per sq. in. leaf area	Average total weight minus roots	Water used per gram dry matter minus roots	Average weight roots	Average total weight including roots	Water used per gram dry matter including roots
	Per cent	*Sq. in.*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
4	98	679	24595	36.2	91.1	270	10.6	101.7	242
4	80	696	25296	36.3	93.1	272	13.7	106.8	237
4	60	747	25719	34.4	100.6	256	13.9	114.5	224
4	40	825	25130	30.5	92.9	270	15.2	108.1	232
4	20	774	19921	25.7	83.2	239	15.8	99.0	201

*Leaf area determined by Prof. E. G. Montgomery's formula, viz., multiplying the length by the width by three-fourths.

TABLE II.—*Quantities of water transpired by plants in each of the five degrees of Soil Saturation (average of 4 plants) during consecutive intervals of 48 hours length. Also quantity of water evaporated from free water surface of 36 square inches area. The weighings were made every two days at 7 P. M. from July 28 to September 2, on Troemner balance.*

Date of weighing	Length of interval	Per cent saturation maintained (5 to 10 per cent variation)					Average of the 5 degrees saturation	*Evaporation from 36 sq. in. free water surface
		98%	80%	60%	40%	20%		
	Hours	Grams water transpired	Grams water transpired	Grams water transpired	Grams water transpired	Grams water transpired	Grams water transpired	Grams water evaporated
July 21 to July 28, 7 P. M.	168	1012	802	1014	1105	904		
July 30, 7 P. M.	48	571	547	646	624	600	598	
Aug. 1, 7 P. M.	48	897	802	989	984	715	877	
Aug. 3, 7 P. M.	48	1392	1363	1576	1450	1142	1384	
Aug. 5, 7 P. M.	48	1526	1460	1676	1574	1180	1483	268
Aug. 7, 7 P. M.	48	1009	1019	1134	1034	816	1002	157
Aug. 9, 7 P. M.	48	1706	1719	1889	1734	1246	1659	218
Aug. 11, 7 P. M.	48	1155	1180	1171	1148	863	1103	134
Aug. 13. 7 P. M.	48	1448	1475	1516	1461	1148	1409	160
Aug. 15, 7 P. M.	48	1250	1312	1274	1307	956	1220	110
Aug. 17, 7 P. M.	48	1584	1726	1666	1586	1270	1566	210
Aug. 19, 7 P. M.	48	1385	1526	1468	1409	1068	1371	180
Aug. 21, 7 P. M.	48	1262	1537	1497	1484	1302	1416	195
Aug. 23, 7 P. M.	48	1039	1156	1075	1117	982	1074	120
Aug. 25, 7 P. M.	48	991	1089	1039	1090	922	1026	125
Aug. 27, 7 P. M.	48	1010	920	796	826	736	858	87
Aug. 29, 7 P. M.	48	1610	1744	1606	1560	1204	1545	236
Aug. 31, 7 P. M.	48	1331	1441	1342	1322	995	1286	150
Sept. 2, 7 P. M.	48	1185	1234	1224	1219	975	1167	181
Sept. 5.......	.....	1232	1244	1121	1096	897	... .	151
Total		24595	25296	25719	25130	19921	... .	2682

*The average evaporation was taken from two 1-gallon glazed stone jars.

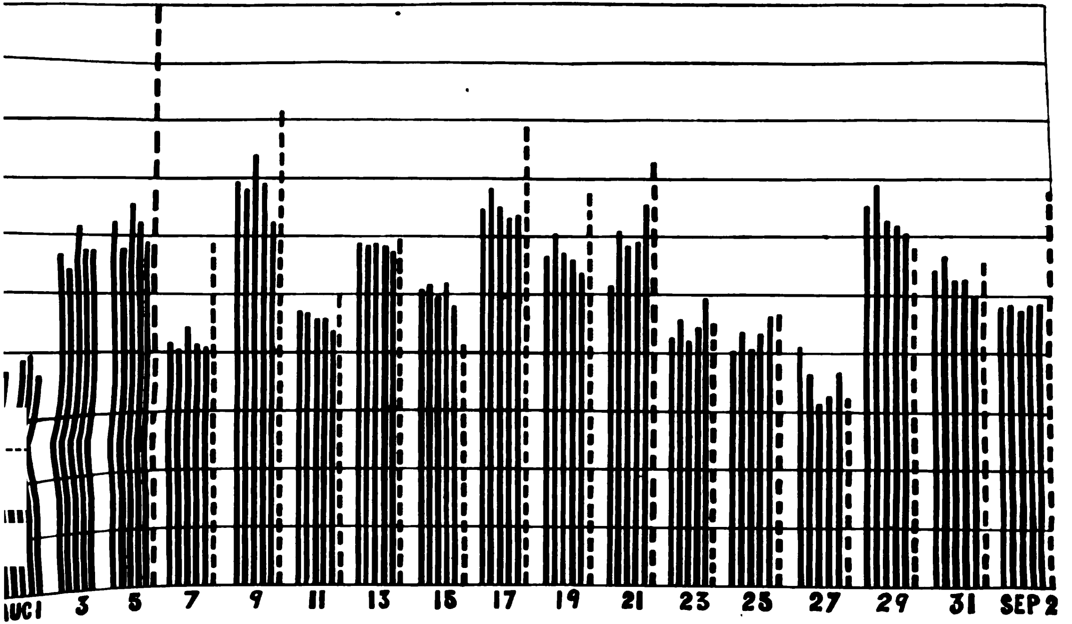


Each group of five lines represents the average actual quantity of water transpired by plants in of the five degrees of soil saturation. The lines in each group from left to right represent the aver- ranspiration from plants respectively in 98, 80, 60, 40, and 20 per cent soil saturation. Each group sents a period of 48 hours. **The column of figures at the left indicates the quantity of water (in s) transpired. The lower row of figures indicates the date on which the readings were made.**

TABLE III.—*Showing per cent of fluctuation in quantity of water transpired by plants in the five degrees of soil saturation, and also evaporated from free water surface.*

The figures indicate what per cent of the total water lost during the experiment—July 21 to Sept. 5—was given off during each interval of 48 hours.

Date of weighing	Length of interval	Per cent saturation maintained (5 to 10 per cent variation)					Evaporation from 36 sq. in. free water surface
		98%	80%	60%	40%	20%	
	Hours	Per cent of total transpiration	Per cent of total transpiration	Per cent of total transpiration	Per cent of total transpiration	Per cent of total transpiration	Per cent of total evaporation
July 30, 7 P. M.....	48	2.32	2.16	2.51	2.48	3.01	
Aug. 1, 7 P. M.....	48	3.65	3.17	3.84	3.92	3.59	
Aug. 3, 7 P. M.....	48	5.66	5.39	6.13	5.73	5.73	
Aug. 5, 7 P. M.....	48	6.20	5.77	6.51	6.26	5.92	9.99
Aug. 7, 7 P. M.....	48	4.10	4.02	4.41	4.11	4.09	5.85
Aug. 9, 7 P. M....	48	6.93	6.79	7.34	6.90	6.25	8.13
Aug. 11, 7 P. M.....	48	4.69	4.66	4.55	4.57	4.33	4.99
Aug. 13, 7 P. M....	48	5.89	5.83	5.89	5.81	5.76	5.96
Aug. 15, 7 P. M.....	48	5.08	5.18	4.95	5.20	4.79	4.10
Aug. 17, 7 P. M.....	48	6.44	6.82	6.48	6.31	6.37	7.83
Aug. 19, 7 P. M....	48	5.63	6.03	5.71	5.60	5.36	6.71
Aug. 21, 7 P. M....	48	5.13	6.07	5.82	5.90	6.53	7.27
Aug. 23, 7 P. M....	48	4.23	4.57	4.18	4.44	4.93	4.47
Aug. 25, 7 P. M.....	48	4.03	4.31	4.04	4.34	4.63	4.66
Aug. 27, 7 P. M.....	48	4.11	3.63	3.09	3.28	3.69	3.24
Aug. 29, 7 P. M.....	48	6.54	6.89	6.21	6.20	6.04	8.80
Aug. 31, 7 P. M. ...	48	5.41	5.69	5.22	5.26	4.99	5.59
Sept. 2, 7 P. M.....	48	4.82	4.88	4.76	4.85	4.89	6.75



—The first five lines in each group represent the per cent of the total water transpired during the nent (July 21-September 5) that was lost during each interval of 48 hours. The lines in each group ft to right represent plants respectively in 98, 80, 60, 40, and 20 per cent soil saturation. The sixth each group represents the per cent of the total water evaporated during the experiment from the 36 inches of free water surface that was evaporated during each interval of 48 hours. The column of at the left indicates the *per cent.* The lower row of figures indicates the date of the readings.

There was a wide variation in the quantities of water transpired during different 48-hour intervals. The greatest difference between two consecutive periods will be noted on August 27 and 29, when the variation was 80 per cent. There was a corresponding variation in evaporation rate from a free water surface. The method used in determining the evaporation rate was rather out of date, but the data obtained will serve fairly well for comparison with the transpiration.

A careful study of Tables II and III and Charts I and II shows that regardless of the soil water content the periodic fluctuation in the transpiration rate was nearly the same with few exceptions. (The slight irregularities can to some extent be accounted for by the fact that in these rapidly growing plants the leaf area was inconstant.) All increased or decreased in quantity of water transpired at about the same relative rate. This would seem to indicate that there is little or no "*stomatic regulative control*" of transpiration as related to soil water content. That is to say, according to the belief of many investigators, one would expect that on days conducive to excessive transpiration the relative increase in quantity of water transpired would be less where the available water supply is small, as a result of stomatic closure in anticipation of wilting, but this was not the case.

The causes of these changes in the transpiration rate are found to be the same as produce changes in evaporation. (Table IV.)

The transpiration changes from one interval to the next can be accounted for in most cases by changes in one or more of the climatic factors. Relative humidity of the air is the chief controlling factor of both transpiration and evaporation. The change from the interval ending August 29 to that ending August 31 is especially interesting in showing the effect of temperature and wind velocity. The strong tendency to vary with humidity has been demonstrated in most intervals, but on this occasion is shown the great effect of temperature and wind velocity on both transpiration and evaporation. Very interesting problems are suggested here on relation of climate to transpiration.

TABLE IV.—*Compilation of four climatic factors, corresponding to the same periods of time as the transpiration readings, also the average quantity of water transpired by the twenty plants, and the quantity of water evaporated from the free water surface tabulated in Table I. (Climatic factors were averaged from hourly readings taken at the U. S. Weather Bureau three miles distant.)*

Date of weighing	Length of interval	Mean temperature (degrees Fahr.)	Mean wind velocity (miles per hour)	Per cent of possible sunshine	Mean humidity	Av. quantity water transpired from the 20 plants	Av. quantity water evaporated from 36 sq. in. free water surface
	Hours					*Grams*	*Grams*
July 30, 7 P. M...	48	79	7.3	88	68.8	598	
Aug. 1, 7 P. M...	48	72.1	5.4	100	62.5	877	
Aug. 3, 7 P. M...	48	81.7	9.3	100	61.5	1384	
Aug. 5, 7 P. M...	48	81.9	7.5	91	64	1483	268
Aug. 7, 7 P. M...	48	72.8	7.5	49.5	72.6	1002	157
Aug. 9, 7 P. M...	48	72.6	6.9	91	62.1	1659	218
Aug. 11, 7 P. M...	48	72.8	7	94	72.2	1103	134
Aug. 13, 7 P. M...	48	71.6	5.3	82	71.7	1409	160
Aug. 15, 7 P. M...	48	77.5	10.2	55	74.9	1220	110
Aug. 17, 7 P. M...	48	79.1	8.1	65	67.7	1566	210
Aug. 19, 7 P. M...	48	68.6	8.7	71	70.7	1371	180
Aug 21, 7 P. M...	48	64.6	6.3	80.5	67.5	1416	195
Aug. 23, 7 P. M...	*48	63.6	10.3	79	67.3	1074	120
Aug. 25, 7 P. M...	48	66	8.1	42	69.2	1026	125
Aug. 27, 7 P. M...	48	72.9	9	53	73.1	858	87
Aug. 29, 7 P. M...	48	78	14.2	75	65.1	1545	236
Aug. 31, 7 P. M...	48	66.6	4.7	93	61.7	1286	150
Sept. 2, 7 P. M...	48	70	6.9	86	69.1	1167	181

*The low transpiration and evaporation on August 23 was due to delay in removing the canvas tent cover.

FERTILITY SERIES

Four sets of five plants each were grown in pure river sand, watered with a complete nutrient solution* of varying strengths, viz., .6 per cent, .4 per cent, .2 per cent and .1 per cent. (Period of growth July 3 to September 17.)

TABLE V.—*Showing correlations.*

No. plants averaged	Strength solution	Saturation maintained	Total dry weight produced	Total water transpired	Water transpired per gram dry weight
	Per cent	*Per cent*	*Grams*	*Grams*	*Grams*
5	.6	100	47.8	11592	243
5	.4	100	74.9	16734	223
5	.2	100	65.3	15577	238
5	.1	100	73.4	19041	259

There was not much difference in the amount of water used per gram dry weight with the different strength solutions. However, not including the 0.6 per cent solution which was too strong for normal development, the amount of water required decreased slightly with an increase in the strength of solution.

The dry weight produced varied but little except with the 0.6 per cent solution; here it was rather low, doubtless due to too strong a solution.

INDICATIONS

The quantity of water consumed by similar corn plants in producing a given yield cannot be materially affected by varying the water content of the soil, other things being equal. No more water is transpired by corn plants of the same parentage growing in wet soil than by those growing in much drier soil, provided it is not

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*Schimper's Normal Nutrient Solution (Concentrated).
Formula:
6 gr. calcium nitrate.
1.5 gr. potassium nitrate.
1.5 gr. neutral potassium phosphate.
1.5 gr. magnesium sulphate.
1.5 gr. sodium chloride.
600 c.c. distilled H_2O.
A few drops of iron.

so dry that the plants wilt. With the soil this dry, somewhat less water is used in producing a given dry weight, but the yield is also decreased.

It seems that there is little or no *stomatic regulative control* which will adjust the rate of transpiration according to the external conditions.

The transpiration rate varies much with the changes in the several climatic factors, relative humidity of the air being the chief among these. The transpiration curve is fairly parallel with the evaporation curve.

It is possible that by knowing the rate of evaporation from a free water surface in any given locality, an approximate idea may be had of the transpiration requirements.

An experiment in which similar corn plants were grown for 2½ months in pure river sand watered with a complete nutrient solution showed no marked relation between the strength of solution and the quantity of water required to produce a unit of dry matter.

The root development is proportionally much greater in dry than in wet soil. Plants which make their early growth in dry soil may then be expected to better withstand a later period of drouth for the reason that they would have a great absorbing surface exposed to the soil particles.

THE UNIVERSITY OF NEBRASKA

TWENTY-FOURTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF

NEBRASKA

FEB. 15. 1869.

PRESENTED TO THE GOVERNOR FEBRUARY 1, 1911

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LETTER OF TRANSMITTAL

THE UNIVERSITY OF NEBRASKA

AGRICULTURAL EXPERIMENT STATION

To His Excellency, Chester H. Aldrich, Governor of Nebraska:

SIR—In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Twenty-fourth Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
Director.

February 1, 1911.

GOVERNOR'S CERTIFICATE

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT,
LINCOLN, February 1, 1911.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR—I hereby acknowledge receipt of the Twenty-fourth Annual Report of the Nebraska Agricultural Experiment Station

CHESTER H. ALDRICH,
Governor.

THE OFFICIAL ROSTER OF THE STATION

THE GOVERNING BOARD

(THE REGENTS OF THE UNIVERSITY)

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TWENTY-FOURTH ANNUAL REPORT

EXPERIMENTAL WORK

The work of the Nebraska Agricultural Experiment Station for the current year has been as follows:

The funds for the Station are secured from three sources, namely: The Adams and the Hatch appropriations are received from the Federal Government. The Regents of the University also set aside certain funds appropriated for general University maintenance which are used to carry on investigation at the central plant. Direct appropriations are also made by the Legislature for certain specific purposes, such as hog cholera investigation, insect pest and plant disease investigation, and the work of the State Entomologist, which funds are expended thru the departments in charge of these lines of investigation for the Experiment Station.

The State makes direct appropriations also for the maintenance of Substations at North Platte, Valentine, and Mitchell, Nebraska.

Under the law the Adams fund must be expended strictly for original research and cannot be used for general administration, for printing, or for demonstration purposes. The Hatch appropriation may be used for general administration purposes but can be used to only a limited extent for demonstration purposes; in fact, the demands upon the Hatch fund for administration and technical lines of investigation are so great that none of these funds are available for demonstration purposes.

The State funds, which come thru appropriations by the Regents to departments in the Agricultural College doing experimental work, are available for all necessary purposes of investigation or demonstration, but are largely used in carrying out the routine investigations which have been planned by the several departments at the Station. Complete plans of work are prepared by these departments at the beginning of each calendar year and submitted to a Station Council for modification or approval. Plans are made for all the funds available so that the work of the Station may proceed in a systematic and orderly manner to accomplish the largest result with the funds available, and practically no funds remain unappropriated for the pursuance of new lines of work until some line of work in progress has been completed. Most lines of work continue for a series of years before final completion. Problems of original research are always pressing for investigation, so that money for demonstration purposes is difficult to obtain from appropriations made for general investigation.

There is need at the present time of a rather large fund to be used for demonstration purposes in cooperation with the farmers of the State. When a new variety of corn, small grain or forage crop has been proved to be of exceptional merit, or a certain method of tillage, of rotation of crops or of orchard management has been shown by the Station to be superior to those now in practice it should be possible for the Station to go out to the farmers and prove to them, by demonstration in each community, that this method is applicable to the farms of their neighborhood. The expense of this line of work would be small for any given community, but if carried on in many places in the State would aggregate a considerable sum of money. Not less than $10,000 per year should be used for the purpose of operating demonstrations of this sort, either upon the country farms or upon private farms in each county in the State. Such cooperation is greatly desired by many farmers who would gladly bear a portion of the expense or possibly all of the ex-

A law should be enacted permitting county commissioners to appropriate money for demonstration farms to cooperate with the central Station, which would furnish seed, expert advice and assistance to make these demonstrations systematic and effective. This would greatly aid in bringing the best agricultural knowledge in the possession of the Experiment Station to those localities in the State where it would be of greatest benefit to the farmers and would demonsrate how to apply new methods in agricultural practice.

LINES OF INVESTIGATION

The lines of investigation carried on under the Adams fund are definitely outlined for the Office of Experiment Stations in the United States Department of Agriculture and are approved by them before investigations in these lines can proceed. At the present time these lines of investigation are as follows:

PLANT DISEASES.—A new form of dry rot of potatoes discovered in western Nebraska has been carefully studied and the life history of the causal organism worked out. It has been shown that this is largely a storage trouble and that the fungus can only infect tubers which have been wounded. This fact indicates the nature of the preventive measures to be applied.

Another serious potato trouble, known as Bundle Blackening, is now being studied. This in some ways is probably a more serious pest than the dry rot. It is very widespread and affects potatoes before digging time. The further fact that this cannot be seen from the outside of the potato renders the disease a very serious one.

A third disease, the common potato scab, is also being studied in connection with the two preceding troubles. Experiments looking toward the prevention of this disease have been carried on for two years but without great hopes of success.

WATER REQUIREMENTS OF CORN.—Water required by the growing plant is related to the relative leaf area rather than the relative dry weight.

Water loss by the plant is correlated with the water loss from a free water surface, the plant apparently not exercising control in this case.

It has also been shown by field tests that the narrow leaf types selected from Hogue's Yellow Dent are more drouth resistant than the broad leaf types of the same variety. The following data give results in field tests for 1908-1909:

Year	Leaf Area		Yield of high leaf corn	Yield of low leaf corn
	High	Low		
	Sq. in.	*Sq. in.*	*Bush.*	*Bush.*
1908	1204	857	50.9	59.4
1909	1395	1127	36.4	44.9
Average	1300	992	43.6	52.1

In both seasons there was a rather severe drouth during earing time.

Selection of Turkey Red Wheat.—In 1903 selection was begun with Turkey Red winter wheat. The product of each selected plant was kept separate and comparisons made under nursery conditions for four years. For the past four years 26 of these strains have been continued under field conditions. The three poorest yielders have averaged 30 bushels per acre. The best three out of the 26 have averaged 40 bushels per acre, while the check plats of the original wheat have averaged 35 bushels. This shows a gain of 5 bushels per acre over the original wheat.

One interesting point bearing on the problem of methods in selection is the fact that quite as many of the selected strains yielded less than the original wheat as yielded better. All our work has shown that we cannot select on the appearance of plants, as to relative value, but the actual field test seems to be the only criterion.

Heavy and Light Seed.—This season completes 11 years' continuous work with two varieties of winter wheat, and 6 years' work with Kherson oats. The method has been to separate on a fanning mill, using only the lightest fourth of the light and heaviest fourth of the heavy. Average results are as follows:

	Yield in bushels per acre		
	Heaviest	Lightest	Check
Winter wheat (two varieties 11 years)	31.8	31.4	31.9
Oats (6 years)	53.8	57.6	58.3

This confirms results secured at other Stations and the opinion that the only way to secure improvement with plants, as with animals, is thru the selection and testing of individuals.

STUDIES IN COMPETITION OF CEREALS.—Records have been kept for 2 years with winter wheat, 2 years with oats, and 5 years with corn. The method has been to plant the seed at various rates. Also to alternate good and poor seed in the row at various rates.

It is too early to report results on chemical and physical changes, but it has been shown that under the thick rate of planting a certain per cent of the plants are crowded out and fail to produce seed. A larger per cent of plants originating from shrunken seed than plump seed are crowded out, thus indicating that natural selection may be a very important factor in maintaining the vigor and yield of cultivated cereals. With corn a higher yield has been obtained with seed grown under thick planting than thin planting.

OATS.—About 200 pure strains of Kherson oats are now being compared in the nursery for yield and quality. Also continuous selections of large seeds and small seeds and large plants and small plants of pure strains are being carried on. Also a number of the large seeded late varieties have been crossed with early varieties to see if we can increase the size and quality of berry on the early oats. Also the wild oat has been used in a number of these crosses to see if it will have an effect on increasing hardiness.

Corn.—Relation Between Yield and Characters of Varieties.—Careful studies have been carried on for several years in testing certain local varieties of corn with standard selected varieties, the idea being to see what general difference has been brought about as a result of selection by different breeds and how it has affected the yield and quality of the corn. Most of the varieties have been collected at various Corn Shows. We have made an effort to see whether there was any definite relation between the type of corn and its ability to yield.

Variety Test for Ensilage.—In 1910 sixteen varieties of corn were grown on the Station farm to determine their value for ensilage. The following table will be of value as indicating the results of one season's work. These varieties would not be likely to retain exactly the same rank as the result of longer trial.

Name of variety	Yield per acre	Per cent of water	Yield dry matter	No. of stalks	Per cent suckers
	Pounds		*Pounds*		
Hogue's Yellow Dent	29220	70.8	8530	7338	23
Leaming	24340	70.6	7155	7740	3
Flour	28780	76.2	6850	8928	29
Kansas Sunflower	26440	74.6	6715	5867	17
McCauley's White Dent	25960	75.0	6490	5868	39
Reid's Yellow Dent	22280	71.5	6350	6684	32
Iowa Silver Mine	28160	77.8	6250	5925	18
Chase's White Dent	23200	73.6	6125	6336	29
St. Charles White	22540	72.9	6110	5754	22
Nebraska White Prize	21680	72.1	6050	4380	28
Johnson County White	21840	73.4	5810	5118	34
Golden Rand	21300	73.4	5665	7040	33
University No. 3	20080	72.4	5540	8418	28
Mammoth Golden Yellow	19000	71.1	5490	4866	39
White Flint	13420	63.3	4925	11550	40
Roselant White	15600	69.4	4775	5804	30

Effect of Crop Rotation Upon Yield.—Work is in progress to determine the effect of crop rotation and continuous cropping upon the productiveness of Nebraska soils. Rotation plats and cropping systems have been established and three years' work has been secured upon this problem at the central Station. Data from the Substation at North Platte are also available covering four years' work upon this subject, and similar work will be carried on at the Substation in Scotts Bluff county, so that we shall soon be able to give the records of yields for completed rotations where continuous grain cropping is followed, where small grain and intertilled crops are alternated, and where small grain and intertilled crops are rotated with grass, clover, and alfalfa. The effect of the application of manure upon land under rotations is also being studied.

Some of the investigations carried on at the central Experiment Station relative to the effect of rotation upon the crop producing power of soils are as follows:

According to information procured from thirty-one progressive farmers, the yields of corn are practically doubled when alfalfa and clover are introduced into a systematic rotation of crops. The average yields of corn produced by the thirty-one farmers before the ground was seeded to alfalfa or clover was 34.5 bushels per acre, while the yield of corn from these same fields was 68.2 bushels per acre after the legume crops were broken up. This shows the very great effect of leguminous crops upon the yields of succeeding crops of corn. These fields were in alfalfa or clover for a varying length of time. The longest time any one of these farmers allowed the land to remain in a leguminous crop was six years. Most of them, however, allowed the leguminous crops to remain for one- or two-year periods.

There are several reasons advanced for the wonderful effects upon the crop yields of corn grown upon alfalfa or clover land, among which is the increase of nitrogen content of soil, as shown by the dark green color of the succeeding corn crop when growing. This increase in nitrogen content has been noted by several Experiment Stations after careful chemical analyses of the soils before and after the growth of leguminous crops.

The amount of organic matter added thru the addition to the soil by the roots, stubble, and fallen leaves has no doubt a very great effect on the increased yield. The past fall the amount of alfalfa roots in the first eight inches was ascertained in an old field and found to be 2.3 tons per acre. When a three-inch stubble was considered in addition to the roots found in the first eight inches, the amount of organic matter per acre in this way was increased to 3.2 tons per acre. These results were obtained from rather limited data and not as reliable as the results will be after more investigations along this line.

Examinations of alfalfa fields made adjacent to the Station Farm, and also in Antelope County, indicate a large accumulation of nitrogen from the roots and the surface growth of clover and alfalfa. One alfalfa field which contained 3 tons of air-dried organic matter in the first foot of soil showed 125 pounds of nitrogen per acre stored in this organic matter. An alfalfa field one year old showed 2 tons of air-dry organic matter with 72 pounds of nitrogen. A clover field on the Station Farm in August, following the sowing of the clover in the spring without a nurse crop, showed 2,500 pounds of dry organic matter in the roots with 44 pounds of nitrogen present, and 4,500 pounds of dry organic matter in the tops with 137 pounds of nitrogen present, or a total of 8,000 pounds of organic matter and 181 pounds of nitrogen accumulated during the season of 1910, which had a heavy rainfall in August. This clover field produced a seed crop the same year the seed was sown. An old alfalfa field in Antelope County showed 5,100 pounds of dry organic matter in the first foot of soil with 105 pounds of nitrogen, and 4,100 pounds of dry organic matter in the next 10 feet of soil containing 65 pounds of nitrogen, or a total of 9,200 pounds of organic matter in the alfalfa roots contained in the first 11 feet of soil, carrying a total of 170 pounds of nitrogen.

SOIL INVESTIGATIONS.—An investigation has been made of some unproductive soils in the Fremont area. The land has recently been thoroly tile drained, but small irregular patches had nevertheless remained unproductive. A very few of these were found to be due to defective drainage—a tile having become clogged. The others were found to be due to the presence of black alkali (sodium carbonate and sodium bicarbonate) either in the surface soil or in the subsoil. This will gradually disappear in the drainage water but its removal will be hastened by treating the spots with gypsum. As a demonstration, a number of these unproductive areas of which the alkali content had been determined were treated with gypsum during the past August. The gypsum will not only hasten the removal of black alkali but will in the meantime change it into a much less injurious white alkali. On one farm near Fremont the unproductive patches were found to be due to the occurrence of large amounts of white alkali, chiefly sodium chloride, in the subsoil. There is no application to be recommended for this, the only cure being to let the rains leach it out. The larger the quantity of water passing thru the soil, the more quickly will the alkali be removed.

The methods for the determination of humus having been exhaustively studied and reliable ones selected, the investigation of the composition of humus is now being carried on.

An investigation is being made of the loess soils in the transition region, which embraces nearly the whole of the State of Nebraska. The object of the investigation is primarily to determine the effect of the amount of the annual precipitation upon the chemical composition and the physical properties of the soil. In Nebraska the mean annual precipitation gradually decreases from the eastern toward the western edge.

WINTERKILLING INVESTIGATIONS.—Investigations are in progress to determine the effect of different moisture content in the soil and different degrees of cold upon the winterkilling of raspberries, apples, and peaches. These temperatures are produced largely by artificial means.

HEREDITY INVESTIGATIONS.—Heredity investigations are in progress to determine whether Mendel's principles of heredity apply in the inheritance of fluctuating variations as well as to discontinuous variations; also to determine whether it is possible to fix characteristics in the case of hybrids, and, if so. how this may be done. These investigations are conducted wholly with plants and are reported in the Twenty-second and Twenty-third Annual Reports.

INJURIOUS INSECTS.—Experiments are in progress to determine the most inexpensive and effective methods of application and minimum strength of wash to destroy the melon aphis and other cucurbit pests. For further information, see article in appendix of this Report.

The life history of the bull pine sawfly is also under investigation, in an effort to stop the ravages of this insect in the natural bull pine area in northwestern Nebraska.

RELATION OF CONFORMATION TO GAINING CAPACITY IN CATTLE. —Experiments have been conducted and are being continued to determine what relation exists between the conformation of the animal and its gaining capacity. At the present time, fifty-two steers of different types are being used for this purpose. Careful measurements are taken of these animals in order to classify them into types and to determine which of the several types used will show the greatest economy in the use of food consumed.

Experiments are also in progress to determine the economy of silage in connection with an alfalfa ration in feeding steers.

Experiments are in progress covering the cost of rearing calves on hand separator milk, adapted to the use of the average cream producer.

RATIONS FOR DAIRY CATTLE.—A comparison of different rations in feeding dairy cattle is in progress, silage being used as an important part of the ration. The dairy herd on the Station farm demonstrates the degree of efficiency and profit to which a herd can be raised by good methods of breeding and by high class care and management, the entire herd of 40 cows producing an average of over 400 pounds of butter for the year 1910.

HOG CHOLERA SERUM.—A small amount of the $5,000 appropriated for the production of hog cholera serum was necessarily spent in building and equipping a small plant. There has been produced to date about 14,000 minimum doses and there will be produced when the appropriation is exhausted approximately 17,000 minimum doses. Serum has been used on 8,800 hogs, averaging in weight 130 pounds, with a loss of less than 7 per cent.

These hogs represented 116 different outbreaks in 39 counties. Sufficient serum is on hand and will be produced to treat about 11,000 hogs weighing 130 pounds. Assuming that 75 per cent of the hogs in an outbreak will die, it is fair to credit the serum with saving 7,500 hogs. As prices have averaged the past year, these hogs would be worth $10 per head. Thus for the $5,000 invested in serum there has been a direct saving of $75,000, while the indirect saving in stopping outbreaks early and preventing the further spread has been considerable.

At the prices quoted above, the cost of producing a dose of this serum has been about 5 per cent of the value of the hog.

There have been used in producing this serum 332 hogs, of which 94 were bleeders, used directly in the making of serum. The other 238 were young shoats which were given cholera in order to furnish the virulent blood used in hyperimmunizing the 94 bleeders, some of which were reloaded and bled a second and third period. This shows that one of the heaviest items of expense is that of producing virulent cholera blood.

From the demand for serum the past fall it seems probable that when the value of serum is known to all hog raisers in the State it will be necessary to have a plant capable of furnishing at least 100,000 doses yearly.

Richardson County has used serum on 1050 with a loss of 60: Franklin County on 1057, loss 58.

Below is given the last ten reports received from cholera outbreaks where serum was used:

Diseased herds in which serum was used.

	Hogs treated		
Ft. Crook	51	4 died.	
Naponee	70	1 died.	
Stella	47	2 died.	
Grand Island	31	3 died.	
Shubert	98	3 died.	
Osceola	62	2 died.	
Benedict	80	3 died.	
Fairfield	172	None died.	
Grand Island	65	15 died.	Month old pigs
Kearney	32	14 died.	All reported sick when given serum.

COOPERATIVE EXPERIMENTS

Inoculating Soils for Alfalfa.—The effect upon the growth of alfalfa of inoculating the soils of Nebraska is being studied in cooperation with about fifty farmers, to determine what conditions are most favorable for the growth and development of the young plant. The form of inoculation practiced in those regions where alfalfa is commonly grown is, to secure soil from a well-established alfalfa field and distribute this soil over the fields newly sown to alfalfa, using only a few hundred pounds per acre, which sufficiently inoculates the soil to materially assist in bringing the young alfalfa forward. The question of spring and summer seeding of alfalfa is also being studied in cooperation with numerous farmers.

Effect of Commercial Fertilizers.—The Station is cooperating with a number of farmers to determine the effect of various kinds of fertilizers upon crop production, in an effort to learn whether such fertilizers will be commercially profitable for use on Nebraska farms. In general it may be said that crops have not responded to commercial fertilizers which furnish potash and phosphorus, but they have generally responded to fertilizers supplying nitrates, indicating that our soils which have been cropped for many years are generally deficient in nitrogen. It is probable that this can be supplied in sufficient quantities by barnyard manure and by practicing rotations in which clover, alfalfa, and other leguminous crops are used. The results of these experiments will be published after sufficient data have been secured.

ORCHARD MANAGEMENT DEMONSTRATIONS.—Spraying demonstrations have been carried on for the last four years to show that profitable crops of apples can be grown where proper care is given to the trees and careful spraying methods are followed. Bulletin 119 (in press) gives the results of the most recent spraying demonstrations.

DEMONSTRATING THE VALUE OF SELECTED WHEATS.—Twenty-four farmers in nineteen counties are each growing eight-acre fields of selected Turkey Red wheats produced here at the Station, as a preliminary test of their value for general use in the State. Results of this test will be reported after harvest in 1911.

A number of farmers are cooperating with the Station in testing local varieties of corn to determine what varieties are best adapted to the several localities.

COOPERATION WITH THE BUREAU OF PLANT INDUSTRY, UNITED STATES DEPARTMENT OF AGRICULTURE.—A Seed Laboratory is maintained in cooperation with the Bureau of Plant Industry, United States Department of Agriculture, to determine the kinds of adulterants and impurities and the percentage of germination of seeds sold upon the market.

The North Platte Station and the Scotts Bluff Station are cooperating with the Bureau of Plant Industry of the United States Department of Agriculture to test different rotations and methods of tillage, to study alkali-resistant crops, and in growing forest trees.

NORTH PLATTE SUBSTATION

The chief lines of investigation have to do with the production of crops and the manner of feeding them to stock. Other lines of investigation are growing forest trees, fruit trees, small fruits, and ornamentals. The year 1910 was the driest year in the last 37 years at North Platte. The total precipitation for the year was 10.7 inches, while the average annual precipitation for the last 37 years is 18.40 inches.

GRAINS

WINTER WHEAT.—Five crops of winter wheat have been produced on summer tilled land. It is difficult to determine the average yield, as there have been tests of rates of seeding and times of seeding, and of different varieties. However, a fair average of wheat planted at the proper time and of the standard variety is 46.7 bushels per acre. This is six bushels more than twice the yield from land not summer tilled. The yield for five years on land not summer tilled, including two years of large rainfall where high yields were made, is 20 bushels per acre. The yield in 1910 under summer tillage ranged from 37 bushels per acre down. The average of a ten-acre field was 30.2 bushels per acre. We recommend summer tilling land for winter wheat in western Nebraska.

Relation of yield of winter wheat to available water.

SUMMER TILLED.

Year	Yields per acre	Available water in upper 6 feet of soil at seeding time	Precipitation from Sept. 15 to July 1	Total water available during season
	Bushels	*Inches*	*Inches*	*Inches*
1907	59.0	....	13.74	....
1908	57.0	7.0*	13.65	20.65
1908	57.0	8.2	13.65	21.85
1909	37.6	7.0	15.80	22.80
1910	30.2	7.6	10.18	17.68

LAND CONTINUOUSLY CROPPED.

1907	24.4	....	13.74	....
1908	20.8	1.9*	13.65	15.55
1908	29.0	2.2	13.65	15.18
1909	19.0	1.1	15.80	16.90
1910	....	....	10.18	....

* In computing the available moisture at seeding time, we have considered 7 per cent as non-available water, and have taken 80 pounds per cubic foot as the average weight of our soil. The hygroscopic coefficient of these soils is slightly above 6 per cent.

In these columns we have considered only the precipitation from September 15, the average seeding date, to July 1, when wheat had completed growth, or, in other words, only the entire growing season.

In computing the total available moisture no consideration was taken of the run-off from the surface of the soil during heavy rains.

SPRING WHEAT.—The four leading varieties of durum spring wheat for the past four years have yielded, on the average, 22.97 bushels per acre and two varieties of common spring wheat during the same time and under the same conditions have averaged 20.96, or two bushels less per acre than the durum varieties. In 1910 the yields of these varieties in the variety test ranged from 2.5 bushels per acre to 4.4. The durum wheat did not show any superiority over the common varieties. Unless we find higher yielding varieties of durum wheat, it would seem wise to continue growing the common spring wheat of the varieties tested. The largest yield of spring wheat in 1910 was 18.0 per acre on a summer tilled plat.

Oats.—There have been several varieties of oats tested. The yield of the best varieties in the variety tests have been from 20 to 50 bushels. Other fields have yielded 70 bushels and a summer tilled plat has once yielded at the rate of 92 bushels per acre. The yield in 1910 was from 5 bushels per acre for late varieties to 23 bushels per acre for early varieties.

The Kherson had held first place without a close rival until the Burt oat was introduced from Kansas in the spring of 1908. During the three years that these two varieties have been grown together the yields from the two have been almost equal.

Barley.—The variety tests of barley indicate that the common Six-rowed barley is the best variety for this region. The average yield of this variety on summer tilled land cropped each alternate year has been 39 bushels as against 20 to 25 bushels per acre on land cropped each year. The yield in 1910 ranged from 5 to 13 bushels on fields cropped each year and 26 bushels per acre on a summer tilled plat.

Relative Yields of Spring Sown Small Grain.—During the last four years corn-stalk fields have been thoroly disked and seeded to various spring small grains to determine their relative yielding capacity. The average number of bushels produced per acre is 38.6 of oats, 35.3 of barley, 34.9 of emmer, 23.4 of durum wheat and 18.4 of hulless barley. This gives a fairly exact idea of the yields of these grains on the Substation farm.

Seeding Broadcast versus Seeding With a Press Drill.—A comparison of seeding broadcast and harrowing, with seeding with a press drill, during four years has shown that, on the average, drilling has increased the yield of spring wheat 7.4 bushels per acre, of barley 7.7 bushels, of oats 10.3 bushels and of emmer 10.8. We have not produced a crop of winter wheat where we sowed the seed broadcast and harrowed it.

Corn.—Variety tests of corn have been conducted during the past six years. The number of varieties or strains grown each year has ranged from 10 to 35. The variation in yield has been from almost a failure to 52 bushels per acre. The ranking of the varieties grown has changed in different years but each season the Substation Calico, which is a medium-sized corn, has been among the leading varieties, and, on the average, may be considered one of the best. No other variety has proven its superior. From all the results of these tests it seems evident that the varieties which have been grown in the western part of the state for several years and properly selected are superior to those brought in from places having different climatic conditions.

The average yield from the 8 leading varieties each season on bench land has been as follows: 1905, 37.2 bushels per acre; 1906, 48.5 bushels; 1907, 32 bushels; 1908, 31.6 bushels; 1909, 30.2 bushels and 1910, 17.3 bushels per acre. The yield of two plats having good stands in 1909 in the variety field was 38 bushels. The average in the variety tests was 25 bushels per acre. The stand was very thin, favoring a good yield during a dry season. The figures quoted are of corn grown on bench land. The yields on table-land have not been as large. The average yield on one-tenth acre plats has been about 22 bushels. However, we do not think that we obtain as large a yield from a small plat of corn surrounded by small grain as from a large field of corn. The small plats are exposed to all the wind and heat while in a large field there is considerable protection for all but the outside rows.

ROTATION AND TILLAGE METHODS

A large number of rotations are being tested to determine the relative value of various crop sequences, of various methods of tillage, of green manure, of barnyard manure, and of grass and legume crops as fertilizers. The crops grown in these rotations are winter wheat, durum wheat, oats, barley, corn, sorghum for forage, rye and peas for green manure, and alfalfa and brome grass in the rotation. These experiments have not been conducted long enough to give data from which general conclusions may safely be drawn. However, the results are of great interest. Summer tillage has increased the yield very materially, tho it has not increased the yield of spring grain sufficiently to warrant urging its adoption as a common practice. Summer tillage has increased the yield of winter wheat more than 100 per cent. The results with winter wheat certainly warrant our urging each farmer in western Nebraska to summer till some land for winter wheat. In a five-year test the lowest average yield obtained on a ten-acre field was 30.2 bushels per acre in 1910, a season of extreme drouth.

Usually summer tilled land has not produced as much corn per acre as land cropped each season, but in 1910 the summer tilled land produced 2½ times as much as the best ordinary method.

SOIL MOISTURE STUDIES.—Determinations of the moisture content of the soil at various depths show that the moisture content may be increased to an indefinite depth, depending on the character of the soil, the precipitation and the tillage. With normal rainfall the moisture content has been increased to a depth of ten feet during one season. Plats that have been summer tilled two or more seasons and have grown a crop each alternate season, show an increase of moisture to a depth of 15 feet, the lowest depth from which samples have been taken.

The data show conclusively that water to the amount of 6 or 8 acre inches may be accumulated in the soil and that the crop uses this water during periods of drouth, greatly increasing the yield.

Summer fallowing or summer tilling is the most practical method of accumulating moisture. This practice is especially recommended for winter wheat. This requires only a few months' tillage during a time of year when there is not much wind, and does not necessitate keeping the soil bare during the winter.

FORAGE CROPS

Cane.—Cane (sorghum) has proved the most valuable annual forage crop. It may be sown on sod that has been broken and thoroly disked. The yield should be about 4 tons per acre during a season of normal rainfall. On old land, it is well to sow the cane after a crop of small grain, where the moisture has been depleted, as a short period of spring cultivation to accumulate moisture may precede the sowing of the cane. Cane may be sown as late as June 15. It should be put in with a press drill at the rate of 4 to 8 pecks per acre depending on the available moisture and the fertility. Cane should be cut when the first heads begin to ripen. If the cane is sown late it will probably not be necessary to cut it until time for frost. This gives the advantage of curing the cane at a time when there is seldom much rain. The feeding value is superior to Platte Valley prairie hay.

Alfalfa.—Alfalfa is the most valuable forage crop that we can grow. On the bench land where the subsurface water is 20 feet below the surface, it produces 4 to 5 tons of hay per acre yearly. The annual precipitation on this bench land does not have a very marked influence on the growth of the alfalfa. The alfalfa on the Substation bench land in 1910 made fair crops when the first 13 feet of the soil did not contain any available moisture.

On the table-land the growth depends entirely on the precipitation. During years of from 18 to 20 inches of precipitation it produced two crops of ¾ to one ton each. It did not produce a crop worth mowing in 1910 tho there was sufficient growth to provide considerable pasture for hogs. The alfalfa on the table uses all the available water to a depth of more than 15 feet. Samples of soil to that depth have shown practically no available moisture, yet the alfalfa remained green, but made little growth.

The value of alfalfa for feeding to stock depends very largely on how it is fed. Where it has been chopped and mixed with ground corn in the proportion of one pound of alfalfa to three pounds of corn, and fed to hogs, it has proved to be equal in value to corn, pound for pound.

FORESTRY.—The area being planted to forest trees in co-operation with the United States Forest Service consists of ten acres of bench land and about fifteen acres of high table-land and canyon land. The planting on canyon land will be largely increased in the future. The planting of conifers on the sides of canyons with north, east, and southeast slopes has been very successful up to the present time, and the outlook is very encouraging. It is necessary only to plant these conifers and to protect them against live stock and fire. The success in planting conifers upon level cultivated land has not thus far been satisfactory but we hope for better results in the future.

The deciduous trees have made very satisfactory growth. The cottonwood and boxelder make the most rapid growth and will probably not be surpassed where temporary shade is the chief consideration. The honey locust gives promise of being a very satisfactory tree. It grows rapidly and has not been affected by winterkilling or by borers. The black locust has proven a total failure on account of the borers. We are of the opinion that the hardy catalpa will prove of little or no value because of winterkilling. The white elm has given satisfactory results, tho it has winterkilled under adverse conditions. The Russian Golden willow promised great results during the first two years but has since deteriorated to such an extent that we feel safe in stating that it is not worth trying. We have mentioned the varieties that have given the best results and also those which have given the worst results. There are many other varieties under test which have neither shown themselves entirely satisfactory nor entirely unsatisfactory.

HORTICULTURE.—An orchard of hardy varieties of apples, plums, and cherries has been planted both on the bench land and on the high table. These orchards are being grown under thoro cultivation methods. The orchard on the bench is now five years old and has made satisfactory growth. The orchard on the table is two years old and while a large number of trees died before they were thoroly established the trees which lived are in flourishing condition.

Ornamental shrubs have generally flourished, especially the common syringa and spirea Van Houtii and the hardy roses.

LIVE STOCK

HOGS.—A herd of 45 brood sows with their offspring are kept for experimental purposes. About 300 hogs are grown and sold annually. The chief lines of experiments are as follows:

(1) How to feed alfalfa hay to hogs.
(2) Comparative value of grains grown in western Nebraska in producing pork.
(3) Cost of keeping brood sows.
(4) Cost of a 50-pound pig.

A large amount of data bearing on these questions is being collected. A brood sow may be wintered on from 1 to 1½ pounds of corn daily per 100 pounds of her weight if she has all the alfalfa hay of good quality that she will eat. During the summer time, after the pigs have been weaned the brood sows do not need any grain when running on alfalfa pasture. The rapidity of the gain bears a close relation to the amount of grain fed, while the cheapness of the grain bears a close relation to the amount of alfalfa eaten. A summary of all the results obtained from fattening hogs on corn and alfalfa indicates that a ration of corn gives about the same rate of gain as a ration of three-fourths corn and one-fourth chopped alfalfa, and that the two rations produce 100 pounds of gain with approximately the same number of pounds of food. That is, when fed in this proportion the alfalfa is worth about the same per pound as the corn. Where a less percentage of alfalfa is fed, the hogs make faster gains but with a larger cost of the corn.

Cattle.—An investigation in wintering cattle to determine the most profitable rations has been carried on for five years. One lot of 100 steers was fed two winters and sold the third summer. A second lot of 108 steers was fed three winters and three summers.

An effort was made to determine the comparative value of different winter rations as follows:

Lot 1 was fed alfalfa each winter.
Lot 2 was fed prairie hay each winter.
Lot 3 was fed cane each winter.
Lot 4 was fed alfalfa and prairie hay.
Lot 5 was fed alfalfa and cane.
Lot 6 was fed prairie hay and cane.

The steers were fed a light corn ration during the first winter.

The total relative gains for the three years were as follows: alfalfa and cane, 100; alfalfa and prairie hay, 97; alfalfa, 96; cane, 90; prairie hay and cane, 89; prairie hay, 80.

While some mixture of alfalfa with other roughness proved the most desirable for producing gain in weight, all lots were fed at a loss, since the price at which they were marketed failed to pay for the feed eaten during the three winter periods and the charge for pasture during the summer periods.

Bulletin No. 117, giving all the details of this experiment, is in press and will soon be ready for distribution.

Baby Beef.—A car-load of calves is now being fed for market under approved methods in an effort to determine whether it contain alfalfa. Also the alfalfa put on flesh that has a tendency to remain on after the animals have been broken and put to work. This is about all that we can state definitely concerning the results of the experiment at the present time. The indications are that colts raised upon alfalfa reach heavier weights at maturity but this cannot be determined positively until the colts are fully matured.

SHEEP.—A preliminary feeding test with a car-load of yearling wethers has been conducted this winter. The car was divided into two lots and both lots fed equal amounts of corn. The forage for one lot was alfalfa and for the other lot alfalfa and prairie hay. More comprehensive experiments are being planned for next winter.

SCOTTS BLUFF SUBSTATION

The Scotts Bluff Substation was organized in 1910 to determine the adaptability of the arid and semiarid portions of Nebraska to agriculture, horticulture and forestry. Experiments were to be conducted both with irrigation and with dry land methods.

Pursuant to an act of Congress authorizing the Secretary of the Interior to set aside certain lands under the Reclamation Service, the Secretary of the Interior withdrew from entry and set aside for purposes of the Experimental Station the southeast quarter of section twenty-one, township twenty-three north, range fifty-five west, located five miles east of the town of Mitchell and seven and a half miles northwest of the town of Scottsbluff, in Scotts Bluff County, Nebraska.

The United States Department of Agriculture, cooperating with the Interior Department, set aside funds for carrying on experimental work and appointed a Superintendent, Mr. Fritz Knorr, to take charge of the Station.

The Legislature made an appropriation of $5,000 for the biennium to cooperate with the United States Department of

Agriculture, placing this appropriation under the Regents of the University.

The Interior Department also made an appropriation of $5,000 with which to erect buildings to enable the experimental work to proceed, and the Regents of the University also used about $2,000 for permanent improvements upon this land.

The land was broken up and some crop was raised during the year 1910, but most of the year was required to subdue the land and get it ready for experimental work in the future.

A thoro test will be made of crop rotations and methods of tillage under dry land methods. Twenty different rotations have been laid out which in course of time will indicate the most desirable combination of crops and methods of tillage for this region.

Under irrigation, tests will be made with sugar beets, potatoes, wheat, oats, barley, and corn and varieties of crops best suited to the region.

The amount of water necessary to use and the most desirable time and method of applying water will also be studied. It is hoped that the work of this Station will do much to assist the farmers in northwestern Nebraska in the development of their agricultural lands.

The United States Department of Agriculture will continue to support this Station and the same appropriation will be asked from the state which was granted for the current biennium.

VALENTINE SUBSTATION

The last Legislature also made provision for an experimental station in the Sand Hills area of Nebraska, which Station, after due investigation by the Regents, was located near Valentine, in Cherry County. The War Department by an act of Congress granted to the Regents of the University an easement in the form of a perpetual lease on a tract of 1,093.52 acres of land so long as it should be used for experimental purposes. This land was a part of Fort Niobrara Military Reservation and is located directly east of the town of Valentine, adjoining the corporate limits.

The Regents, not wishing to place permanent improvements upon this land, were voted, by the town of Valentine, a deed to forty acres of land adjoining the land above described and have proceeded to erect a substantial cement block house and a cement block barn upon this land, also making other improvements which exhausted the appropriation. The entire tract of land was fenced and several interior fences built and about sixty acres of land was plowed to be used experimentally in 1911.

This land is fairly typical sand hill land and will be used to determine whether or not such land will produce agricultural crops profitably. Some alfalfa has been sown upon the land and all the different varieties of alfalfa and leguminous crops will be tested to determine their suitability to this region. Corn and sorghums will also be tested and all the grasses which promise success upon light sandy land.

It is proposed to establish a herd of dairy cattle and to operate a demonstration dairy farm, bringing out the methods in dairying which will be most profitable in the region.

Some effort will also be made to establish trees and determine the suitability of this region for growing timber.

STATION STAFF

Within the past year the following changes in the Station staff have taken place.

Mr. G. Herbert Coons, Assistant in Agricultural Botany, resigned January 1, 1911, his position being filled by Mr. George K. K. Link.

Mr. James Cowan was elected Superintendent of the Substation at Valentine, Nebr., on March 1, 1910.

Mr. Fritz Knorr was elected Superintendent of the Experimental Substation at Mitchell, Nebr., on March 1, 1910.

IMPROVEMENTS

Since the last Annual Report, a brick and cement steer feeding plant has been erected on the University Farm, at a cost, when completed, of $10,000. This building is constructed of hollow tile covered with stucco, is equipped with iron stalls and cement mangers and floors and a slate roof. It has, connected with it, a hollow tile silo. This barn will be used exclusively for experimental cattle feeding.

At the North Platte Station the following improvements have been completed: A dwelling-house, costing $4,400; water service, costing $2,100; five concrete cattle and hog sheds with galvanized iron roofs, costing $1,750; a galvanized iron machine shed, a corn crib, and horse sheds, costing $1,400.

At the Valentine Substation, Superintendent's dwelling, cement block, costing $4,200; horse barn, cement block, costing $2,500; wire fencing, costing $1,400.

At the Scotts Bluff Substation, frame barn, machine shed, and wire fencing, costing $2,075.

PUBLICATIONS

Bulletins giving the results of investigation in the Experiment Station are published in editions of 20,000 to 25,000 each, except where limited editions are published upon some technical subject. These bulletins are distributed free of charge to any resident of the State making application. There is at the present time a regular mailing list within the State of 17,000 names. These are continually being added to, and it is desired that all farmers who are interested in the publications of the Station should ask to be placed on the regular mailing list.

The publications of the Station since those named in the last Annual Report are as follows:

Twenty-third Annual Report. Presented to the Governor February 1, 1910. 5,000 copies.

Bulletin No. 114 (Substation Bulletin No. 5) (Vol. XXII, Art. IV). Storing Moisture in the Soil. By W. W. Burr. Distributed May 3, 1910. 27,000 copies.

Bulletin No. 115 (Vol. XXII, Art. V). The Determination of Humus. By F. J. Alway, E. K. Files, and R. M. Pinckney. Distributed June, 1910. 5,000 copies.

Bulletin No. 116 (Vol. XXIII, Art. I). Economical Beef Production. By H. R. Smith. Distributed December 15, 1910. 32,000 copies.

Bulletin No. 117 (Substation Bulletin No. 6) (Vol. XXIII, Art. II). Growing Feeder Steers in Western Nebraska. By W. P. Snyder. Distributed February 1, 1911. 32,000 copies.

Bulletin No. 118 (Substation Bulletin No. 7) (Vol. XXIII, Art. III). Growing Crops in Western Nebraska. By W. P. Snyder and W. W. Burr. (In press.) 40,000 copies.

Press Bulletin No. 32. Testing Seed Corn. By E. G. Montgomery and C. W. Pugsley. Distributed March 8, 1910. 105,000 copies.

Press Bulletin No. 33. Construction and Use of the Road Drag. By L. W. Chase. Distributed May 19, 1910. 50,000 copies.

FARMERS' INSTITUTES

Several members of the Experiment Station staff have assisted in Institutes during the current year. One hundred and fifty-seven Institutes were held in 1909-1910, and 100 Institutes in 1910-1911. The falling off in the number of Institutes held is due to a lack of funds to carry on this work, which it is hoped will be remedied by the present Legislature.

Among the new lines of work taken up by the Farmers' Institute is the Extension School, or the holding of a school of agriculture for six days in some town or rural community, where the teachers give systematic instruction in two or three leading subjects. There is a very great demand for instruction of this character. It is important at this time that an appropriation be made for agricultural extension which would permit very greatly increasing the number of Extension Schools. Not less than $25,000 annually should be available for Farmers' Institute work, Extension Schools, and small demonstration plats or farms, to be operated in cooperation with the county poor farm or some interested farmer in the region. A law should be passed by the Legislature permitting the County Commissioners to appropriate a limited amount of money to be used in cooperation with the Extension Department in the University for conducting demonstrations in the several counties of the State.

ORGANIZED AGRICULTURE

The meetings of Organized Agriculture have been largely attended and are a source of great interest and profit to those in attendance. A movement is on foot to incorporate under a single organization and to ask for a small appropriation from the State to assist in the annual meetings and in publishing the papers presented before the various societies. If this movement is successful it will materially assist in bringing strong talent to the meetings of Organized Agriculture and still further enhance their value.

THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA

FINANCIAL STATEMENT

ADAMS FUND

RECEIPTS

Received by the University (state) treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1910, under the act of Congress approved March 16, 1906 (Adams fund)	$13,000 00	

EXPENDITURES.

Salaries		$8,593 52
Labor		1,162 78
Postage and stationery		65 74
Freight and express		54 47
Chemical supplies		323 06
Seeds, plants, and sundry supplies		394 42
Feeding stuffs		106 53
Tools, implements, and machinery		393 89
Scientific apparatus		1,436 82
Live stock		268 40
Traveling expenses		200 37
	$13,000 00	13,000 00

FINANCIAL STATEMENT—Continued

HATCH FUND

RECEIPTS

Received by the University (state) treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1910, under the act of Congress approved March 2, 1887 (Hatch fund)	$15,000 00

EXPENDITURES

Salaries		$9,467 57
Labor		262 38
Publications		2,367 22
Postage and stationery		691 30
Freight and express		56 40
Chemical supplies		74 76
Seeds, plants, and sundry supplies		215 76
Fertilizers		142 62
Feeding stuffs		148 53
Tools, implements, and machinery		82 35
Furniture and fixtures		265 40
Scientific apparatus		156 42
Live stock		690 84
Traveling expenses		363 45
Contingent expenses		15 00
	$15,000 00	15,000 00

FINANCIAL STATEMENT—Continued

SUPPLEMENTAL FUNDS

RECEIPTS

Moneys received by the University (state) treasurer from other sources than the United States, for the use and benefit of the experiment station and substations for the year ended July 31, 1910:

Balance, July 31, 1909	$2,345 75	
Sales of stock, produce, etc., for year ended July 31, 1910	28,511 73	
EXPENDITURES		
Salaries		$2,141 23
Labor		3,152 40
Postage and stationery		376 87
Freight and express		563 63
Chemical supplies		84 72
Seeds, plants, and sundry supplies		2,408 49
Feeding stuffs		7,541 95
Tools, implements, and machinery		702 31
Furniture and fixtures		265 36
Scientific apparatus		433 77
Live stock		2,168 25
Traveling expenses		913 13
Contingent expenses		81 40
Buildings and land		1,335 77
Balance, July 31, 1910		8,688 20
	$30,857 48	30,857 48

FINANCIAL STATEMENT—Continued

STATE PROJECTS

APPROPRIATIONS BY THE STATE

SUBSTATION (NORTH PLATTE)

Legislative appropriation from the state general fund for the benefit of the experimental substation at North Platte, for the two years ending March 31, 1911	$25,000 00	
Expenditures to July 30, 1910, for superintendence, supplies, labor, live stock, feed, seeds, machinery, tools, and betterments of the plant		$24,994 93
Balance July 30, 1910		5 07
	$25,000 00	25,000 00

TWO NEW SUBSTATIONS

Legislative appropriation for two new substations from the University tax fund for two years ending March 31, 1911 (available second year only on account of litigation)	$20,000 00	
Expended, account of Scotts Bluff substation to July 30, 1910		$1,385 98
Expended, account of Valentine substation to July 30, 1910		4,056 07
Balances July 30, 1910:		
Scotts Bluff appropriation		3,614 02
Valentine appropriation		10,943 93
	$20,000 00	20,000 00

FINANCIAL STATEMENT—Concluded

STATE PROJECTS

APPROPRIATION FOR FARMERS' INSTITUTES

Legislative appropriation from the state general fund for maintenance of farmers' institutes, for the two years ending March 31, 1911........	$20,000 00	
Expenditures, to July 30, 1910, for superintendence, clerical service, labor, lecturers' and workers' service and expenses, printing, supplies........		$12,868 96
Balance, July 30, 1910...........................		7,131 04
	$20,000 00	20,000 00

J. S. DALES,
Financial Secretary.

Lincoln, Nebr.
January 2, 1911.

APPENDIX

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(A NEW SAWFLY ENEMY OF THE BULL PINE IN NEBRASKA)

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A NEW SAWFLY ENEMY OF THE BULL PINE IN NEBRASKA

BY MYRON H. SWENK

INTRODUCTION

Nebraska is usually thought of as a typical prairie state devoid of any important amount of native timber, and while this is undoubtedly true as applied to most of the state, nevertheless it is equally a fact that a very considerable area in the rougher western and northern counties is more or less covered with a thin growth of the Bull Pine or Rock Pine, *Pinus scopulorum* (Engelmann) Lemmon, the same species as occurs commonly thruout the Rocky Mountain region from Montana and Wyoming to Arizona and New Mexico. Actually, however, as compared with many other states, our supply of native coniferous trees is quite limited, consequently we are prone to value them even more highly than if our possessions of such timber were more extensive, and at once become interested in any inimical condition which threatens to seriously damage or destroy these trees

EXTENT OF PINE-CLAD AREA

Our pine-clad region centers in what is known as Pine Ridge, a high crest of land which enters the state from Wyoming about fifteen miles south of the South Dakota boundary line and extends southeastwardly across Sioux county, then curves northeast across Dawes county and enters South Dakota from Sheridan county. The Ridge is highest at its western end, about 5,300 feet, but falls rapidly as we proceed eastward. In the higher, southeastwardly directed portion of the Ridge the pines occur mainly on the sides of the north escarpment, following the upper sides and edges of numerous abruptly descending, rugged and deep canyons into the Hat Creek basin, a flat area nearly 1,400 feet lower than the top of the Ridge and composed largely of bad lands. However, a few pines occur on the southern escarpment along the sides of the canyons emptying into the upper Niobrara or Running Water. But after the northward curve the Ridge becomes divided into sections by the White river valley and the entire broad table of the now much lower and flatter Ridge is covered with a scattering growth of pines, these tending to concentrate along the sides of the canyons tributary to the White river.

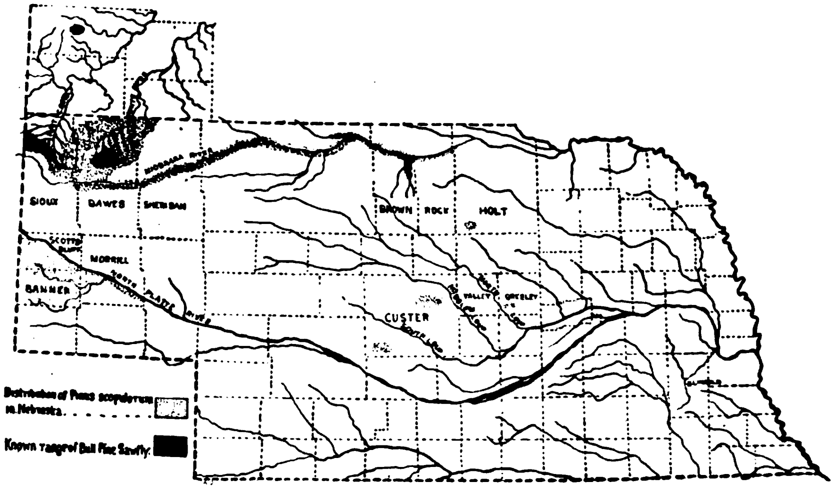

Fig. 1. Distribution of *Pinus scopulorum* in Nebraska, and known range of the Bull Pine Sawfly.

The pines continue unbrokenly along the bluffs and ridges of the Niobrara river, the sources of which drain the southern section of the Ridge, especially along its southern bank, to over half way across the state in western Holt county, also extending back a short distance on the sides of several of the larger tributaries of the Niobrara, the last ones being Plum and Long Pine creeks in northern Brown county. Another pine-clad area is found along the North Platte river, in Scotts Bluff and Morrill counties, and pines also occur abundantly on the high hills drained by the Pumpkin-seed and Lawrence creeks in Banner county. Other isolated patches occur in the Loup valley in Custer, Valley, and

Greeley counties. It is thus obvious that more territory is involved in the distribution of the Bull Pine in Nebraska than would casually be supposed.

DISCOVERY OF THE BULL PINE SAWFLY

For two or more years past occasional indirect reports have reached us to the effect that the pines in the Ridge were being attacked and defoliated in certain spots, but the injury was usually erroneously attributed to the Black Hills Pine Bark-beetles by those reporting it. Our first intimation of the real cause of this reported damage came in a letter received at the Experiment Station from the editor of the Crawford Tribune dated the 23d of last May (1910), containing the statement that the pines twelve to fourteen miles east of that place were being stripped of their needles by worms, as many as twenty to every six or seven inches on the twigs, and intimating that the settlers were becoming considerably alarmed over the situation. Along with the letter came several specimens of the worms, which we placed in a rearing cage. An examination of these worms at once showed them to be a large sawfly larva which after careful comparisons could not be identified with any described slug known to attack pines.

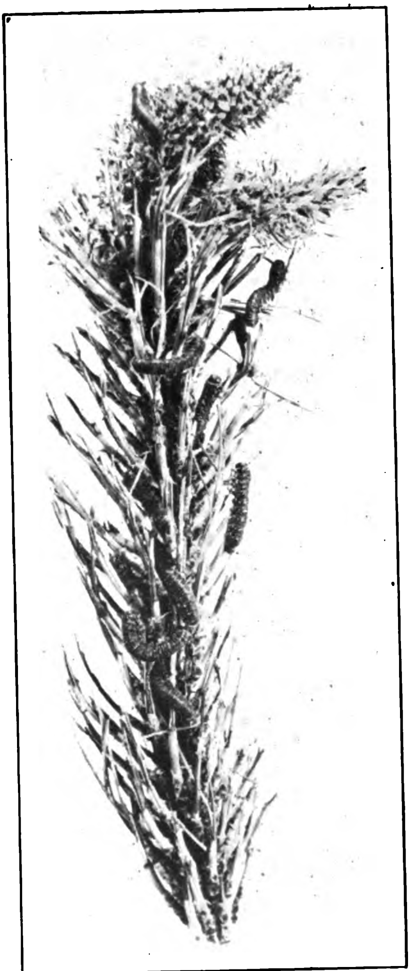

Fig. 2. Clump of larvae on old Bull Pine tip.

INVESTIGATIONS OF THE SITUATION

It was decided that as apparently the slugs were present in unusually large numbers over an extensive scope of territory the situation merited further investigation, and accordingly I departed for Crawford on May 28 and spent the next two days in the infested district examining the conditions and collecting material for rearing purposes. Subsequently during the year three other trips of investigation were made to the affected area by various members of the entomological force, Professor Bruner and I spending June 10 and 11 there, Professor Bruner and Mr. J. T. Zimmer July 7 to 19, and Mr. Zimmer alone November 27 to December 10. The data covering the intervals between these trips were supplied by Mr. Theodore Soester, who kindly agreed to keep the insects under surveillance for us, he being the man who first reported the slugs and incidentally also the owner of a considerable portion of the timber upon which they were destructively at work.

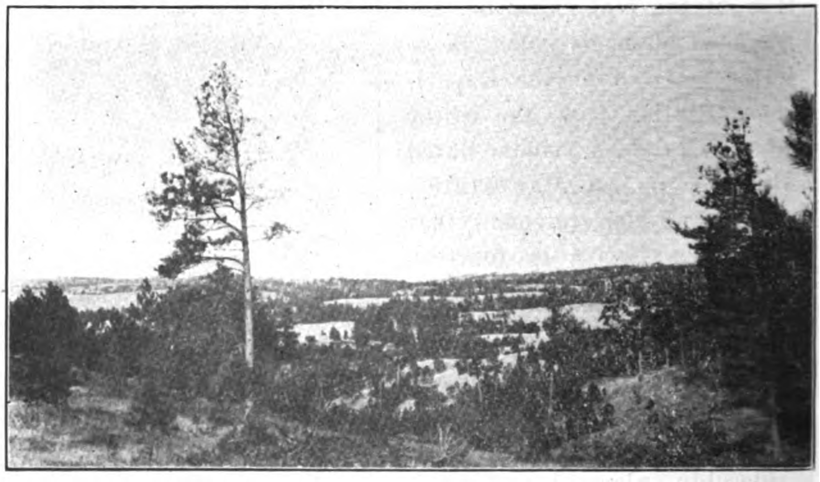

Fig. 3. The infested area, looking northeast along the Ridge, November 28, 1910.

THE CENTER OF INFESTATION

On my initial trip I soon discovered that the region of greatest infestation lay in an elevated portion of the Ridge almost directly east of the town of Belmont, its southwestern corner having upon it a well-known eminence known as Squaw Mound which gives a commanding view of the entire canyon of Squaw creek, a small stream flowing northwardly for some distance before joining the White river. The pines along this valley for about four miles to the northward and about eight miles to the eastward were carefully examined and the conditions of damage were found approximately uniform over this area, covering practically a township. The exact extent of the injuriously infested area to the northward and eastward we have not determined, as we did not reach its limits, but to the westward and southward of Squaw Mound the evidences of sawfly attack rapidly diminished and soon disappeared entirely.

OTHER INFESTED AREAS

At different times other portions of the Pine Ridge were examined to determine if the sawfly was at work elsewhere. On June 11 and again at various times between December 6 and 10 the territory along the White river from the center of the northeastwardly curve (at Crawford) to where the Ridge separates from the river valley (near Andrews) was carefully examined and only one point of noticeable infestation was found, that being an isolated patch of defoliated trees near Andrews observed June 11. Monroe canyon in the Hat creek

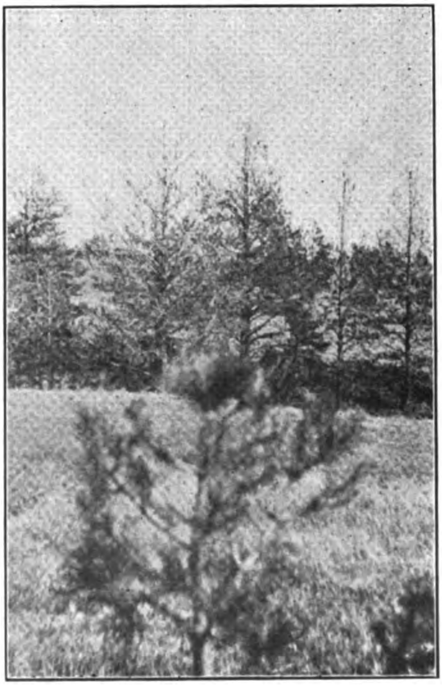

Fig. 4. Clump of Bull Pine showing defoliation by the sawfly in the spring, May 29, 1910.

basin was traversed nearly its entire length without finding any trace of the sawfly. We have, however, in previous collecting expeditions collected adult females of the sawfly in Monroe and Warbonnet canyons and other points in the basin, so that we know it occurs practically thruout this region. We have specimens from the Black Hills near Custer. South Dakota, also. There are thus four known areas of occurrence, but in all probability the species is generally distributed thruout the Ridge and adjacent portions of the Black Hills.

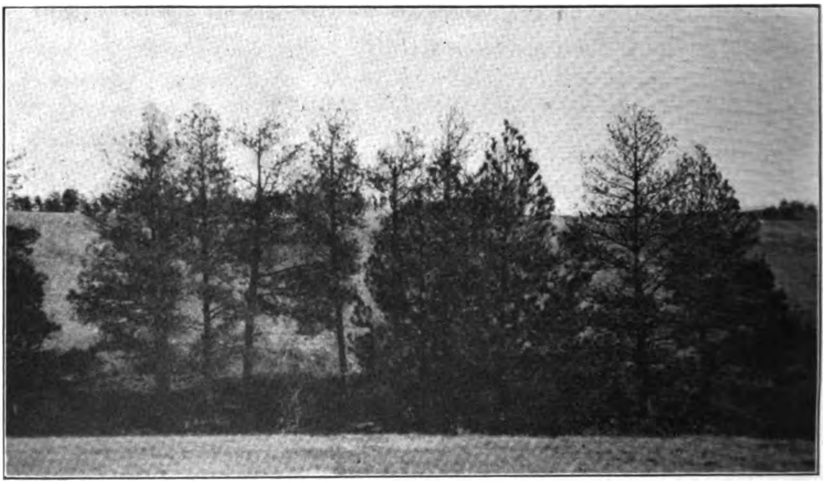

Fig. 5. Same clump as shown in preceding figure reattacked in the fall, November 28, 1910.

CHARACTER OF THE ATTACK

When first investigated it seemed that the younger growth of pines was particularly heavily attacked, especially those forcing their way up the sides of the newer shallow gullies and out onto the plains. Practically every clump of such trees was largely if not almost completely stripped of the needles. These young trees, however, showed considerable resistance to the sawfly attack, and in July it was observed that many were growing new leaves and seemed vigorous and in a fair way to recovery,

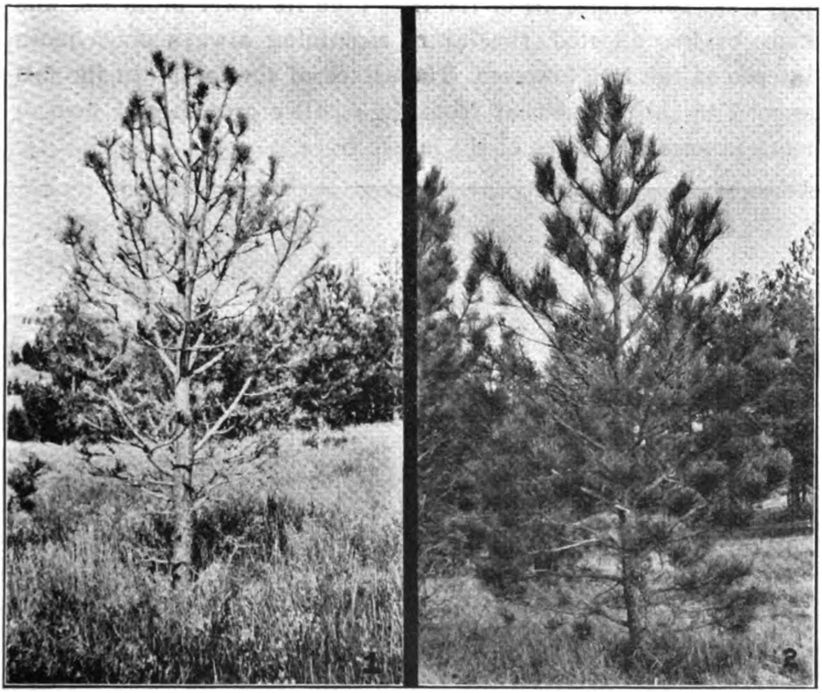

Fig. 6. 1, A young Bull Pine sending out new needles after the spring attack, July 8, 1910; 2, same tree with well-developed new tips, November 28, 1910.

which was what actually happened where the same trees were not subjected to reattack in the fall. The accompanying figures show the appearance of a clump of trees on May 29 and November 28 showing defoliation in the spring and again by a second attack in the fall after a partial recovery during the summer (Figs. 4 and 5), and also the appearance of the same young tree on July 8 and November 28 where there was no second attack (Fig. 6).

Among the older trees in the deeper slopes the injury involved more particularly the tops of the trees, this portion being stripped of its needles, usually for the upper one-eighth or one-sixth of its height, while the lower branches usually escaped injury; but sometimes all of the tree, even its lower branches, was more or less affected, the injury remaining always much more intense at the top, however. The attack of the larvae in the fall seemed to shift somewhat from the smaller growth and involve more intensely the tops of the larger trees.

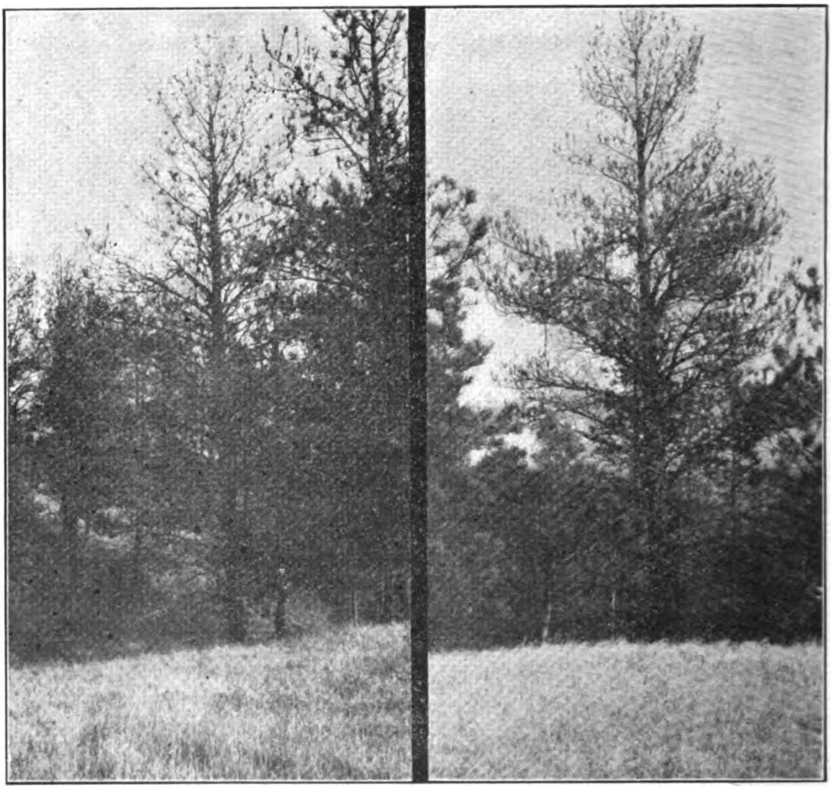

Fig. 7. Views of two large Bull Pines showing typical injury at tops of the trees, November 28, 1910.

In our rearing cages it was found that these larvae, while they preferred the foliage of the Bull Pine, also fed eagerly upon the needles of the closely related Austrian Pine (*Pinus austriaca*) and to a limited extent upon the Scotch Pine (*Pinus sylvestris*) when these were offered them.

NAME OF THE SAWFLY

After rearing the adults, a series of specimens of both sexes was submitted to Mr. S. A. Rohwer, the sawfly specialist of the United States National Museum, and after a careful study of this material he states that they represent a new species closely related to *Diprion* (formerly *Lophyrus*) *townsendi* (Ckll), which latter species is known only from the unique female type which was found dead under a pine tree in the White mountains of New Mexico in August, 1898, by C. H. T. Townsend. Our species, together with *townsendi* and another new species from the mountains of northern Mexico, form a district group, distinguishable at a glance by the broadly transversely yellow striped tergum in the female, which will be elevated to generic rank by Mr. Rohwer in a forthcoming paper on this interesting group of sawflies intended to cover the species of the world. For the present we can refer to our species as the Bull Pine Sawfly. Both sexes of the Bull Pine Sawfly are handsomely colored, the female being black with the thorax, head, and legs rufous and the body variously striped with bright yellow, while the male is black relieved by creamy yellow marks on the head, abdomen, and legs.

APPEARANCE AND HABITS OF THE LARVAE

The larvae of the Bull Pine Sawfly are conspicuously gregarious and occur in bunches of twenty-five up to fifty or seventy-five among the needles at the tips of the branches. Here they cling closely with their abdominal legs, the caudal curl also tightly wrapping the needles, and in feeding begin at the tips of the needles and devour them toward their bases. There is an evident sexual disparity in size, the females being distinctly the larger. From the known larvae of related species of *Diprion*—*lecontei*, *abboti*, *fabricii*, *abietis* and *pratti*—our larvae are at once distinguishable by their dark green, unspotted but longitudinally lined body and bright red head.

In the spring the larvae are almost continually engaged in a

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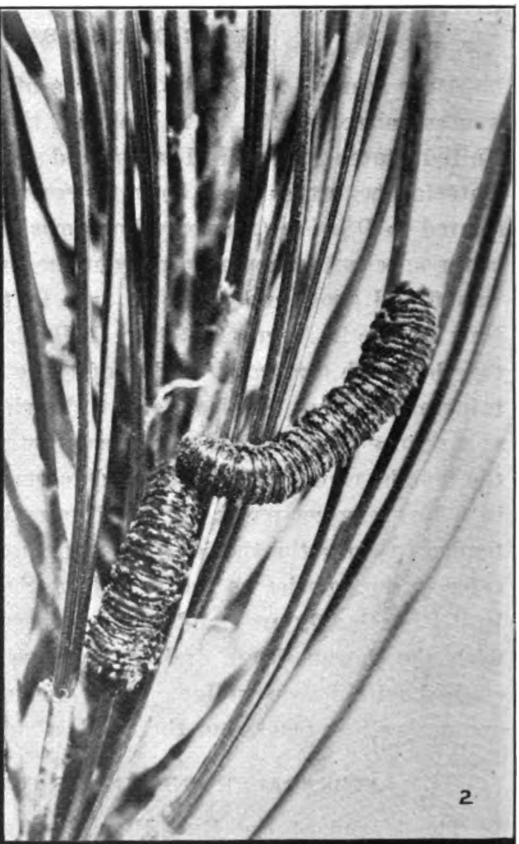
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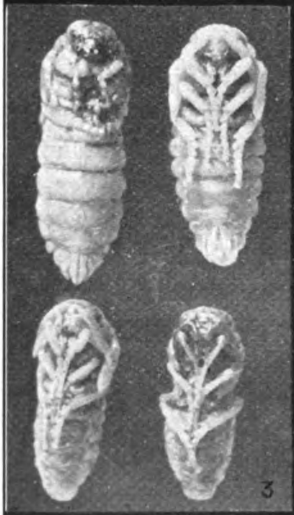
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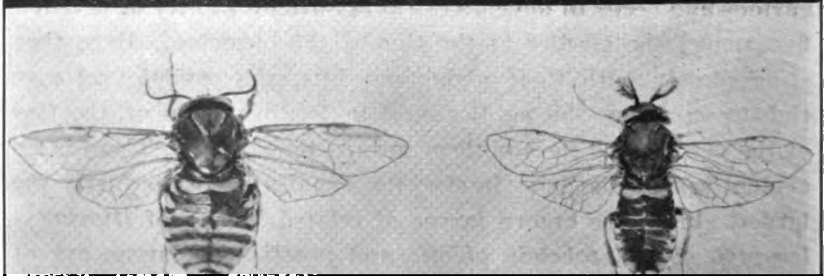


peculiar motion, that of throwing back the fore end of the body to the middle or a little beyond until it is almost at right angles to the needle upon which the larva is attached and then quite suddenly snapping back to the horizontal position. On May 29 a clump of larvae was observed for four hours during the middle of the day and not for a moment did they cease this motion. Obviously this characteristic proves a valuable protection to the larvae from the parasites, numbers of which were flitting about among the trees, as these insects seemed exceedingly averse to attacking a moving larva. In the fall, when the larvae are considerably smaller, this throwing back of the body is exaggerated until the head and tail almost touch, but there is little or no snapping return to the normal position at this time and the posture is generally assumed only when the larvae are disturbed in some way, being leisurely abandoned soon after the disturbance ceases. The larvae at this time also have the habit of exuding from their mouths drops of a white viscous fluid, especially when disturbed in some way.

THE LARVAE IN SPRING

When the weather becomes warm enough in the spring the larvae which have hibernated on the trees begin feeding vigorously and soon reach full growth. At the same time the defoliation due to this feeding soon becomes evident, and, by the first of May when the larvae are nearly full sized and become less ravenous, the tops of the trees have become conspicuously denuded. About this time they stop feeding to any great extent in the daytime and soon thereafter begin dropping to the ground to spin up. At the time of my first visit to the region, on May 29, the larvae were still very abundant on the trees but much less so than they had been a week or ten days previously, according to the reports of the settlers. By June 10 they had almost disappeared from the trees and only here and there could be found in any abundance, trees that were covered with them twelve days previously being now deserted except for a few straggling individuals. The small trees in the bottom of the gullies seemed to have the most larvae at this time. On July 7 and 8 no full grown larvae whatever could be found, but on the 8th a single small cluster of larvae in a very early stage of development was found, these apparently representing the young of the new generation.

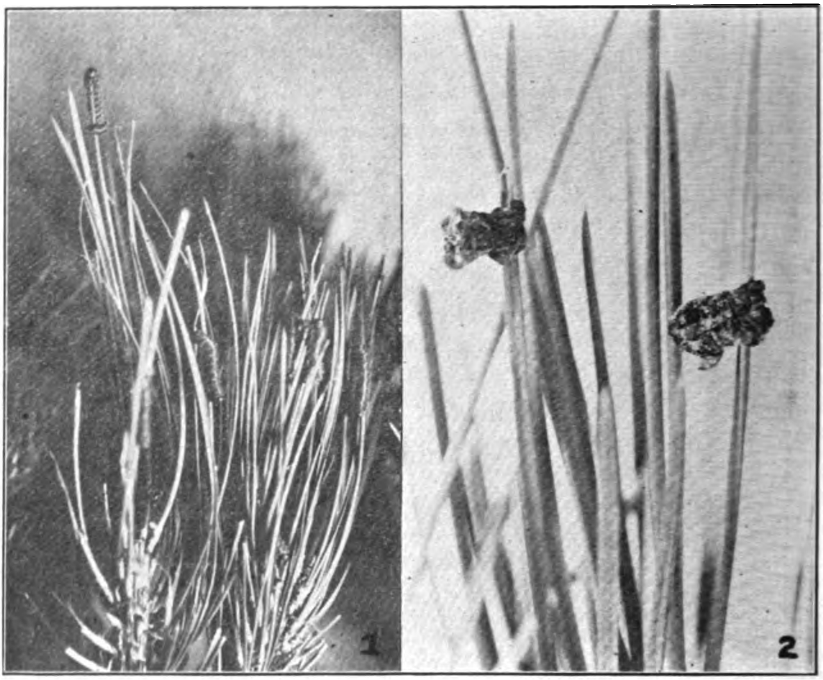


Fig. 9. 1, Larvae feeding on pine needles; 2, molted skins of the larvae clinging to the needles.

SPINNING UP OF THE LARVAE

When the larva is full grown it undergoes a final molt and becomes of a bright green color without the fuscous lines characterizing the preceding stages. It then soon drops to the earth and burrows into it. After several hours the construction of the cocoon is commenced. The cocoon when completed is an oval, thickwalled, silken affair, measuring 14x7 mm. in the female and 12x6 mm. in the male, which at first is whitish in color but later turns a dark reddish brown. We have not observed the species spinning up among the needles of the pine as often occurs with the White Pine Sawfly (*D. abboti*) and the Fir Sawfly (*D. abietis*).

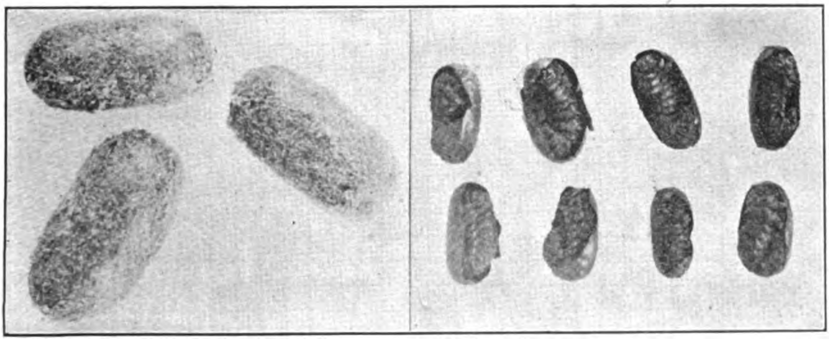


Fig. 10. Female and male cocoons of the Bull Pine Sawfly, and position of sawfly larvae within the cocoons.

A cursory search for fresh cocoons on the surface of the ground was made May 29 but none were found, tho with little doubt there were plenty in the soil. On June 10 a search beneath the trees in the hard dry clay soil under the mat of dead needles resulted in the unearthing of 467 of them in a quarter of an hour and within a space of only three or four square feet. Practically all were at a depth of an inch and one-half to two inches and were congregated in particular abundance along the sub-exposed roots of the tree. On July 8, 1967 cocoons were collected due probably to most of the cocoons in the ground during June and July having given up their occupants in the wave of high emergence which occurred during the latter month.

Of the larvae in our rearing cages the first spun up (en transit) May 25 and the next May 30, and this continued until

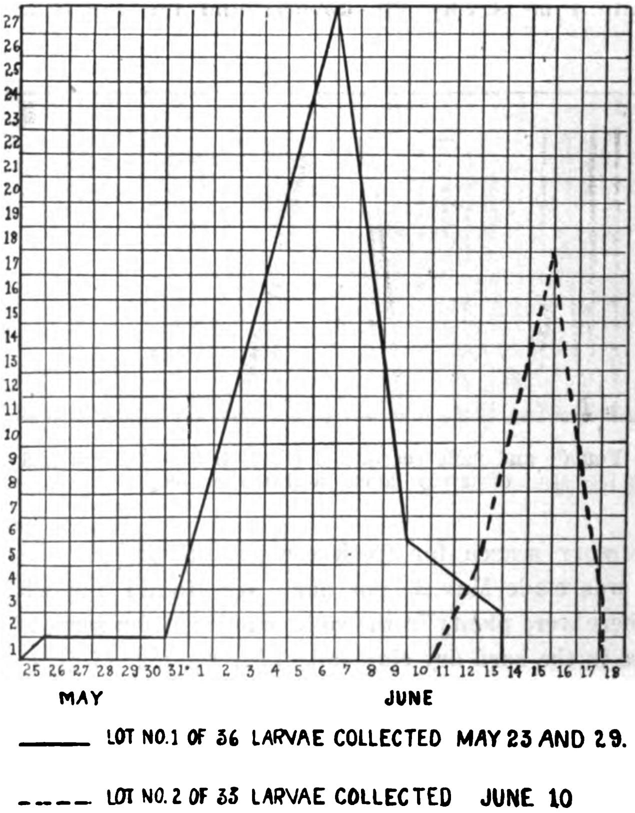


Fig. 11. Spinning up of larvae of the Bull Pine Sawfly.

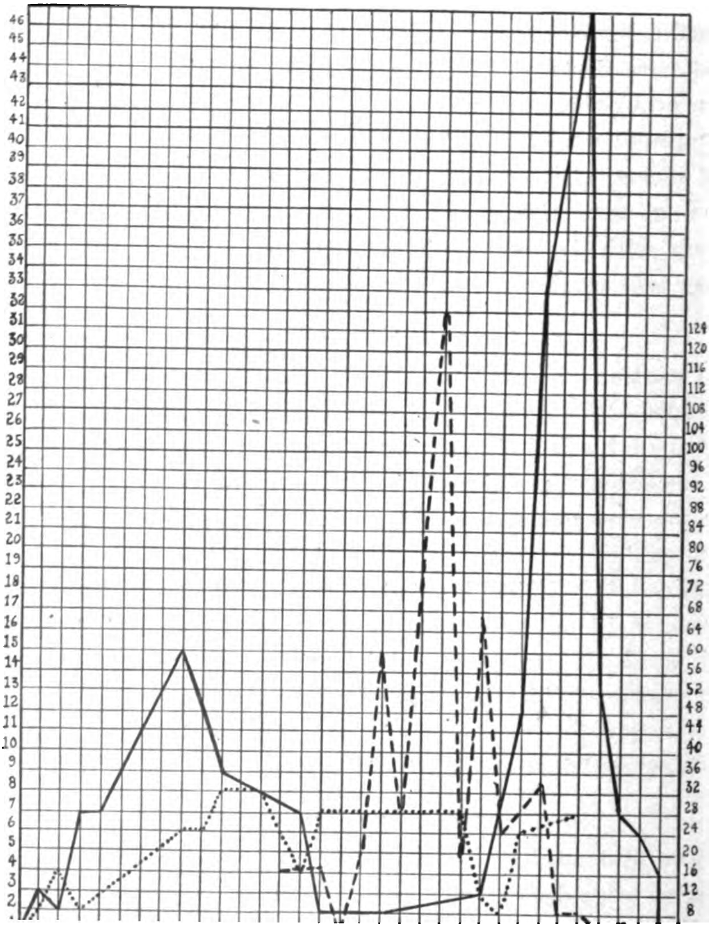
of this experiment to determine the spinning period was greatly hindered by the extreme prevalence of a bacterial disease, discussed a little later, among the larvae, which in spite of our utmost care destroyed them with great rapidity. Of 27 cocoons spun up by these larvae June 6, six were barely under the top of the ground while the other 21 were at a depth of two and one-half inches. Of five that spun June 9, all were about one inch down, as were also two that spun cocoons June 13, thus tallying closely with the findings in the field, allowing somewhat for the looser soil in the breeding cages.

PUPATION OF THE LARVAE

Pupation apparently begins in early June and certainly is extended over a month tho I have no definite data as to the actual length of the individual pupal period. Closely related species are accorded a pupal period of two weeks. On July 8, twenty-five more cocoons were opened in the field and about half of them contained pupae, the others larvae. From the same lot 85 examined July 13 had in 60 of them (70 per cent.) untransformed larvae, in 13 (15 per cent.) pupae, ten females and three males, and in 12 (15 per cent.) adults, nine females and three males. The pupae at this time were in various stages of development from newly formed to subadults. The two sexes can easily be distinguished in the pupa by both size and color.

EMERGENCE OF ADULTS

The first adults were found in the field June 10, when two females were discovered partially hidden away among the pine needles, both apparently freshly emerged and exceedingly gravid, during several hours' search by two persons. But on July 7 and 8 the adult females were common on the pine tips, tucked away among the bases of the needles and were also observed coming out of the ground in obvious numbers. The males were less in evidence than the females, only a few being found and these on the outside of the tips where they crawled about much more actively than the sluggish females.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In the out-of-door breeding cages at Lincoln the first adults emerged June 28 and continued emerging in gradually increasing numbers to July 5 when there was a temporary decline which immediately preceded a period of exceedingly rapid emergence extending for a little over a week, July 18 to 25, during which 376, or over 67 per cent. of the total number of adults, emerged, the last adult appearing July 29. The adults were very short lived in the cages, and in no case observed by us did they survive over a week. The females were slightly the more tenacious of life, as out of 29 individuals 5 lived one day, 9 two days, 1 three days, 4 four days, 6 five days, and 4 seven days, while of 30 males, 9 lived one day, 12 two days, 1 three days, and 8 four days. In the field, however, there is but little doubt that the adults have somewhat greater lease of life, since they have been repeatedly collected in early August. In emerging, the adult neatly cuts away the top of the cocoon in a clean somewhat spiral line and pushes aside the lid thus formed, forcing itself out of the cocoon and up thru the soil to the outside. Of 549 adults emerged, 271 were males and 278 were females.

OVIPOSITION OF ADULTS

Actual oviposition of the sawfly was not observed either in the field or rearing cages. During the field work in the region July 7 to 9, altho adults were common no females were detected in this work, and in spite of efforts continued thru the season we could not induce the reared females to oviposit in or upon fresh pine twigs placed in the cages, altho their abdomens were distended with eggs and they died in that condition. Most probably the oviposition is essentially like that of *D. pini* in Europe and *D. abboti* in America, namely, that the female deposits her eggs beneath the epidermis on one of the flat sides of the pine needles, sawing a slit with her ovipositor and pushing the eggs into the slit. The fact that the injury is so markedly more intense in the tops of the trees would suggest that perhaps the insects prefer that portion of the tree for ovipositing, which may also account in part for the failure to make field observations on this point.

The egg of the sawfly, as determined from dissections, is yellowish white or creamy, cylindrical with rounded ends, slightly curved, and measures 2x6 mm. In ten freshly emerged females dissected July 13 the number of eggs ranged from 88 to 144 with an average of 129.

THE LARVAE IN THE FALL

As has already been noted a small clump of young larvae of the new generation was found in the field as early as July 8, these probably representing exceedingly accelerated individuals, the progeny of adults which issued in early June. By October 27 the larvae have become half grown and have made very obvious defoliations. About this time they apparently cease active feeding and do not grow perceptibly until the following spring. November 27 Mr. Zimmer found them still about half grown and their old molted skins were hanging to the needles quite commonly. In this condition they were hibernating.

HIBERNATION OF THE LARVAE

Hibernation in the Bull Pine Sawfly takes place in two distinct ways, both involving the larval stage, namely, as half-grown larvae in the trees and as fully developed larvae tightly packed in the cocoons in the ground.

The half-grown slugs wintering in the trees are gathered in small clusters on the pine tips at the bases of the needles and are for the most part quite motionless, reacting sluggishly on stimulus and more energetically if artificially warmed. On the warmer days they are noticeably more active and may even scatter over the tips and feed somewhat. At this time if they are dislodged by high winds or other causes they fall to the ground and remain there until sustained warm weather revives them sufficiently to enable them to crawl up the trees and regain their position on the tips. One day in the winter of 1909-10 following a storm these slugs were seen on the snow in considerable numbers by the school children and the fact was reported by them to their parents. On warm days early in the past spring (1910) other settlers reported having seen these larvae crawling up the trunks of the trees in large numbers.

Mr. Zimmer has made some interesting notes on the hibernation of these slugs. November 27 was cold and they were inactive but the next day was warmer and they moved about somewhat but did not feed. During the night a light snow fell and the morning was rather cold so that the slugs were again inactive and tightly curled about the bases of the needles. On November 30 everything was white with a heavy frost one-half to three-quarters of an inch deep on the northwest side, and as a heavy fog clouded the atmosphere so completely that the sun appeared dimly only at rare intervals everything remained frosty the entire day. The larvae were covered with this frost and were so stiffened that it was necessary to unbend them in order to pick them from the tips, yet when some were carried in the palm of the hand they became active again. The first of December was clear with a temperature of 14 degrees and a cold northeast wind, and the larvae remained inert and could be dislodged in quantities if the branches were struck a sharp blow, until about 4 P. M., when the sun had warmed things up considerably and the slugs began to move about. The next day was pleasantly warm and the slugs had not only revived sufficiently to move about but in the afternoon they left their retreats at the bases of the needles, spread out over the tips and actually commenced feeding. December 4 a heavy snow fell during the night and morning and later there developed a blizzard with a sweeping northwest wind. The slugs were completely covered with snow and frozen so stiff that they could be snapped in two with the fingers like dry twigs. A bunch of these frozen slugs, however,

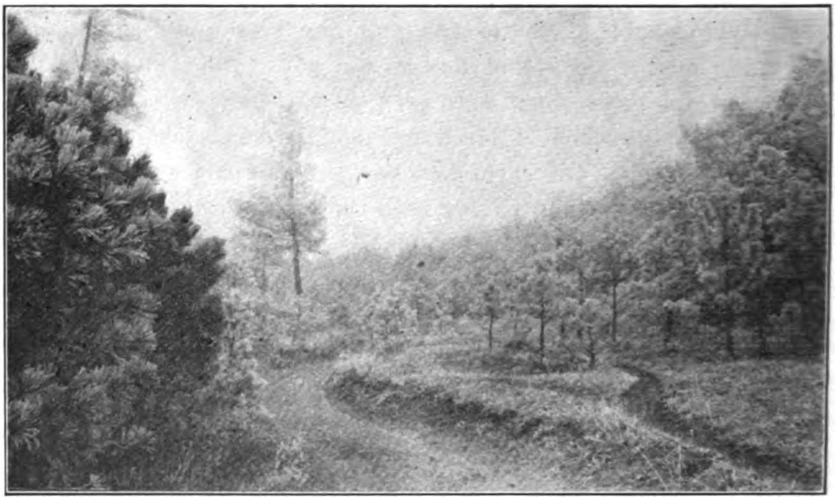

Fig. 13. Frost of November 30, 1910, in which the larvae were frozen on the trees.

placed in the house near the window thawed out in a very short time and commenced to feed on the twigs.

During the winter of 1910-11 we kept in our out-of-doors breeding cages at Lincoln several hundred half-grown larvae which had been collected in the infested region on December 4 by Mr. Zimmer and brought back by him. This gave an excellent opportunity to study the resistance of these larvae to low temperatures. At 3:00 A. M. on New Year's Day, 1911, a storm came on which gained in intensity during the day, so that by 7:00 P. M. the temperature had dropped to 7 degrees below zero with a 32-mile north wind. The preceding day had been warm with a maximum temperature of 42 degrees and a minimum temperature of 32 degrees. Below zero weather continued over January 2 and until noon of January 3, the temperature being less than —8 degrees from 8:00 P. M. on January 2 to 10:00 A. M. January 3, and reaching a minimum of —16 degrees at 7:00 A. M. January 3. On January 2 at 11:00 A. M. the larvae were frozen absolutely stiff; on January 4 at 5:00 P. M. at a temperature of 27 degrees the larvae were still more or less frozen but were pliable, tho motionless and apparently dead; on January 5 at 11:00 A. M. at a temperature of 44 degrees the larvae were active as usual, moving about on the twigs and characteristically exuding the white viscous matter from their mouths when disturbed; on January 6 at the same hour they were completely and normally active, apparently none the worse for having been in a frozen condition for a period extending over approximately 4 days. The larvae were subjected to such alternate freezing and thawing thru the winter, and yet almost every individual has survived.*

The larvae which hibernate in cocoons in the ground are obviously those which have spun up after becoming full grown the preceding spring, at least in part. The 69 cocoons which were spun up by the larvae in our breeding cages between May 26 and June 17 on examination December 19 showed that the contents of 57 of them had become desiccated or decomposed and the cocoon was filled with white fungous matter or dark mold. Of the remaining 12 cocoons, two contained adult ichneumons, two had reared tachinids and the other eight, all from larvae spun up June 6 and 9, contained apparently healthy active larvae, exactly like those now to be found in half of the cocoons collected June 10 and July 8 in the field. November 30 and December 1, cocoons were dug up in the field and contained the same thing, active slugs and parasite adults. In none of these is there shown any tendency toward the completion of their transformation into pupae, and without doubt this is deferred at least until spring.

THE LIFE CYCLE

The foregoing observations on the various stages of the Bull Pine Sawfly seem in all essential points amenable to either of two quite distinct conceptions of its life cycle. It may be that the brood of adult sawflies abroad in the late spring and summer deposit eggs, probably very soon after emergence, which develop into larvae, the very first of which reach obvious size in early July and all of which become at least half grown by fall and on the advent of cold weather cease feeding and hibernate in clusters on the trees. They resume feeding in the spring and complete their growth, begin to drop from the trees in May, completely deserting them during June, then enter the ground and spin their cocoons. Part of the larvae in these cocoons pupate immediately, and early in June begin giving up adult sawflies, while others continue pupating thru June and July and adults continue emerging into August, the maximum of emergence occurring during latter July; the other part of the larvae do not thus transform at once but remain unchanged thru the summer, fall and winter following, pupating the following spring and in a few weeks emerging as adults. In other words, some individuals of the same generation complete their life cycle in a single year, spending only a very brief period as untransformed larvae, while other individuals require two or possibly even more years, remaining as untransformed larvae in the cocoons for at least eleven months and pupating normally in the spring of the second year. Some such arrangement as this is the currently accepted life cycle of *Diprion pini* in Europe, wherever that species occurs with only a single brood of adults annually.

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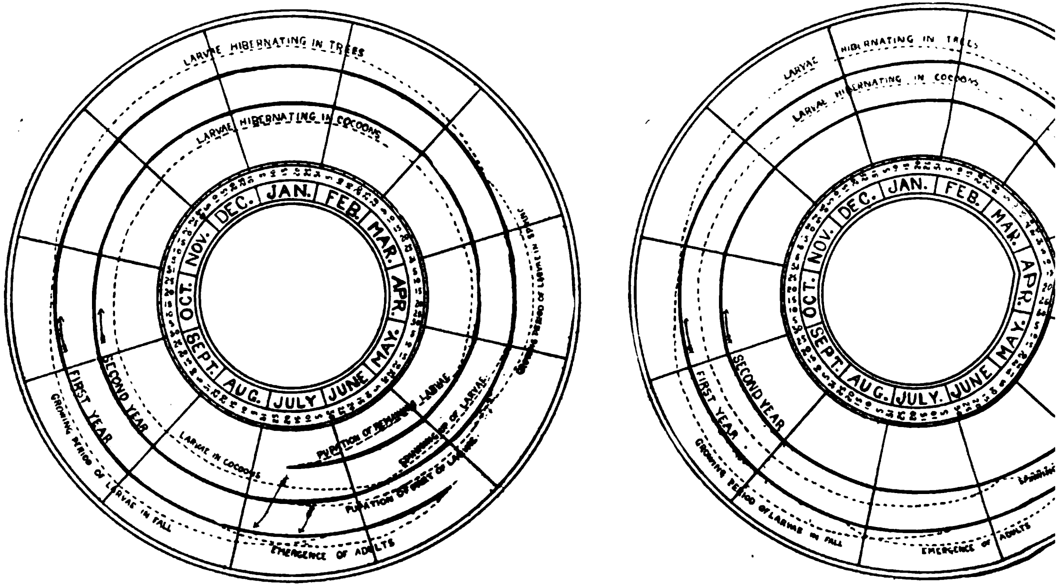
* With the warm days of spring the bacterial disease again appeared and they died very rapidly, the two last ones dying June 1, 1911, in a fully grown condition; none of them spun up.

But this explanation in the case of our species has against it the fact that none of the 69 larvae which spun up in our breeding cages gave up adults during the summer, and that all of them now alive are still untransformed larvae. Moreover, from the lot of 467 cocoons collected June 10, just after the maximum of the spinning up, only 163, or 35 per cent., gave up adults while from 1800 collected July 8 only 386, or 21 per cent., gave up adults; a rather disproportionately small immediate emergence it seems to me and one in which the percentage of


LARVAE HIBERNATING IN TREES
LARVAE HIBERNATING IN COCOONS
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EMERGENCE OF ADULTS
LARVAE IN COCOONS
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LARVAE
HIBERNATING IN TREES
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FIRST YEAR
SECOND YEAR

Fig. 14. Diagram illustrating the two possible life cycles of the Bull Pine Sawf

emergence rapidly diminished as new cocoons were added to the soil. Of course neither of these facts is conclusive evidence, nor perhaps even exactly indicative, yet it has appeared to me that more likely it requires in all cases two years for the completion of a generation and that there are two distinct broods appearing in alternate years; that is, the brood of adults which appeared in the summer of 1910 produced larvae which have hibernated on the trees in a half-grown condition, and which will complete their growth and spin up in May and June of 1911, remaining in their cocoons until the spring of 1912 when they will pupate and emerge as adults. Similarly, the adults of the summer of 1911 will come from larvae which spent the winter of 1910-11 in the cocoons, and which are the progeny of the adults of the summer of 1909.

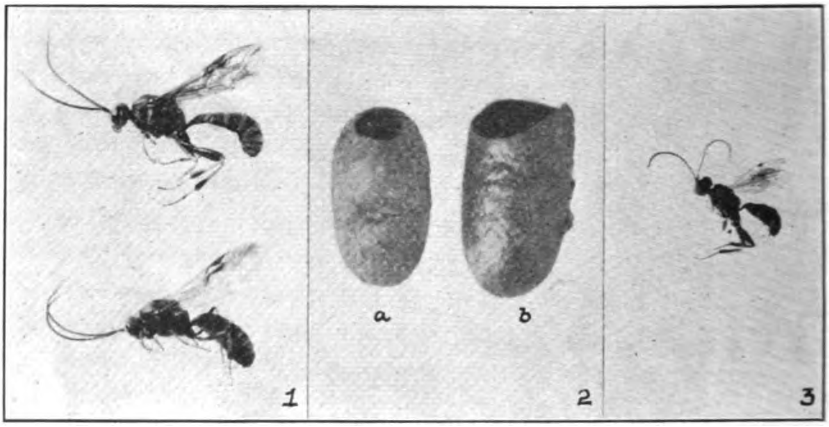

Fig. 15. 1, *Exenterus lophyri*, female above, male below; 2, cocoons of the Bull Pine Sawfly showing exit holes of (a) the *Exenterus* parasite and (b) the Bull Pine Sawfly; 3, *Phygadeuon* (*Mastrus*) n. sp., another ichneumonid parasite of the Bull Pine Sawfly.

THE CHIEF PARASITE OF THE BULL PINE SAWFLY

The Bull Pine Sawfly has a powerful natural enemy in the form of a tryphonine ichneumonid which has recently been described by Mr. H. L. Viereck in the Proceedings of the United

States National Museum as *Exenterus lophyri,* from specimens which we sent him for determination. It is a large handsome insect with conspicuous yellow marks on the face and yellow bands on the abdomen and legs.

Its chief season of flight is in the spring. It was abundant in the field both May 29 and June 10, especially on the latter date when it was obviously more abundant than earlier in the season, and even as late as July 7 and 8, after the full grown larvae had disappeared, it was still common in the field. There is also more or less of an emergence in the fall, as from both the lots of cocoons collected June 10 and July 8 there was a long drawn out but feeble emergence, especially from the latter lot, beginning October 8 and continuing to November 1, reaching its maximum October 17.

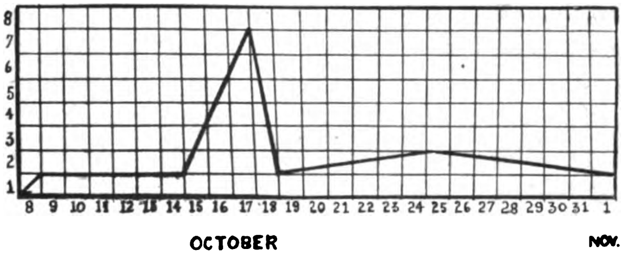

Fig. 16. Emergence of adults of *Exenterus lophyri* in the fall.

The actual method of attack by this parasite was observed repeatedly in the field during the spring. The *Exenterus* approached the slug carefully, almost invariably from behind, its antennae directed forward and vibrating nervously, advancing one leg after another with the utmost deliberation until it had placed itself within striking distance of its victim; then, swiftly about half to contain larvae, most of which were parasitized. Of 60 cocoons containing larvae July 13, 30, or 50 per cent, were parasitized, this representing 35 per cent. of 85 cocoons examined. At this time the parasite larvae were of varying size, from about 1 mm. long to large enough to practically fill the cocoon, while one pupa was found. On November 26, 50 cocoons from this same lot contained 14 *Exenterus,* 1 dead pupa, 3 dead adults and 11 living adults which flew about when released; 24 contained living larvae, two of which were parasitized by small *Exenterus* larvae, while 12 had the contents desiccated with half of them showing remains of the parasite, a total parasitism of 44 per cent. Similarly, cocoons examined in the field November 30 contained both adults and small larvae attacking the slugs. There is no doubt that most of the *Exenterus* larvae reach full growth in the fall, pupate, and transform immediately to adults, some of which emerge as shown above, but most of which remain in the cocoons with the remains of the nearly consumed sawfly and do not emerge until the following spring. The parasite thus probably has a generation annually. While in the cocoon the adults are enclosed in a thin, transparent membranous envelope which contains at the posterior end the pupal exuvium, and they remain in this envelope until emergence. By the time the parasite larva has reached full growth the slug is almost completely consumed, only its head sclerites and integument remaining.

When the female *Exenterus* emerges, whether in the spring or fall, its abdomen is so tremendously distended with eggs that flight is at first a difficult matter. Examination of the abdominal contents reveals literally thousands of very small, hemispherical, chalky white eggs. The overwintering adults in the cocoons

OTHER PARASITES OF THE SAWFLY

Besides the *Exenterus,* two other species of ichneumonids, both cryptine, were reared from the cocoons. From cocoons collected July 8 a species of *Phygadeuon,* determined by Mr. Viereck as new and belonging to the Ashmedian genus *Mastrus,* was reared July 18, and on July 23 a second specimen. On July 24 another larger species of *Phygadeuon,* also new, and belonging to Ashmead's interpretation of *Bathymetis,* was reared. These two ichneumonids were, however, not seen in the field and are probably of inconsequential importance.*

On the occasion of my first investigation of the sawfly, May 29, tachina flies in great swarms were present thruout the region exactly as they mass during an army-worm invasion. These flies occurred not only among the trees but in the fields where they sought out the warm sunny exposures. At the home of Mr. Soester tachinids were swarming about the front porch and sunny side of the house and proving as much of an annoyance as the house fly under aggravated conditions, and they were at that time, I was informed, much less numerous than they had been a week or ten days previously. By June 10 these flies were no longer conspicuous tho still present among the trees in such numbers as to be a valuable control factor, and numerous slugs were found with tachinid eggs upon their bodies. Several species of tachinids were represented in these swarms but the commonest one was *Euphorocera claripennis.* Of four larvae which spun up June 11, there emerged on July 1 a tachinid of this species and on July 8 another. Another interesting species of dipterous parasite of the Bull Pine Sawfly is an undetermined bombyliid which emerged July 25 from a cocoon collected in the field July 8.

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* Viereck has since described the smaller species as *P.* (*Mastrus*) *neodiprioni* and the larger one as *P.* (*Bathymetis*) *patulus* in Proc. U. S. Nat. Mus. XL, pp. 193 and 195.

VERTEBRATE ENEMIES OF THE SAWFLY

The ground under the infested trees on May 29 and on all subsequent trips was thickly strewn with empty cocoons from which the contents had been consumed or emerged. Undoubtedly many of these were simply cocoons formed by the larvae, usually parasitized, which did not enter the ground to spin up but did this on the surface. Some of these empty cocoons showed the clean cut of the emerged sawfly, more the small emergence holes of the *Exenterus,* very many the large ragged hole of the tachinids, but many could not be placed with any of these and seemed more to have been forcibly opened from without. At places there were dozens of these empty cocoons in a single square foot under the tree, and most were bunched near the mouths of small tunnel-like burrows which in many spots closely ramified the ground under the trees. Obviously these were the runways of some sort of vole or wild mouse but we are unable to trap any of the inhabitants and are yet ignorant as to the identity of the useful little mammal. Chipmunks (*Eutamias pallidus*) were also in part responsible for opened cocoons, and Mr. Soester reported having observed these little animals actually engaged in digging out the cocoons and devouring their contents in early July.

The sticky consistency and exceedingly resinous odor of the slugs would not be expected to render them particularly inviting to birds, yet some species do feed upon them to a limited extent. On November 30 Mr. Zimmer collected a pair of Mountain Pine Grosbeaks (*Pinicola enucleator montana*) which had been feeding heavily upon the slugs, their crops being distended with them.

of a bacterial disease which swept them away rapidly. Of 181 larvae collected May 29, 136, including all which had not spun up or been preserved as specimens, had died of this disease by June 20, while similarly in the lot of 242 larvae collected June 10, 202 had perished by June 22. In brief, of the 425 larvae collected, 338 or 80 per cent. of the whole had died of this disease in a little over three weeks time. The same disease was present in the field, tho much less intensely so, as on June 10 the bodies of numbers of larvae which had died of the disease were noted among the needles. The disease was marked by a short period of extreme sluggishness of the larva, during which its body became soft and after death a rapid blackening and putrefaction.

Also a good number of the cocoons which have been opened at various times have had the entire interior filled with a mass of snowy white fungous filaments. Whether this is really an entomophilous fungus or one simply growing on the bodies of larvae and pupae of the sawfly or its parasite which have died from other causes has not yet been learned.

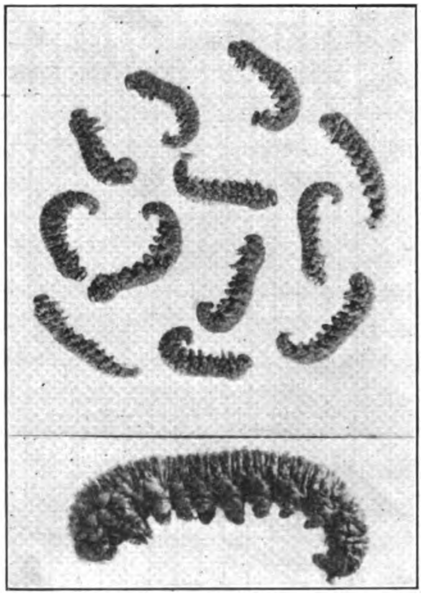
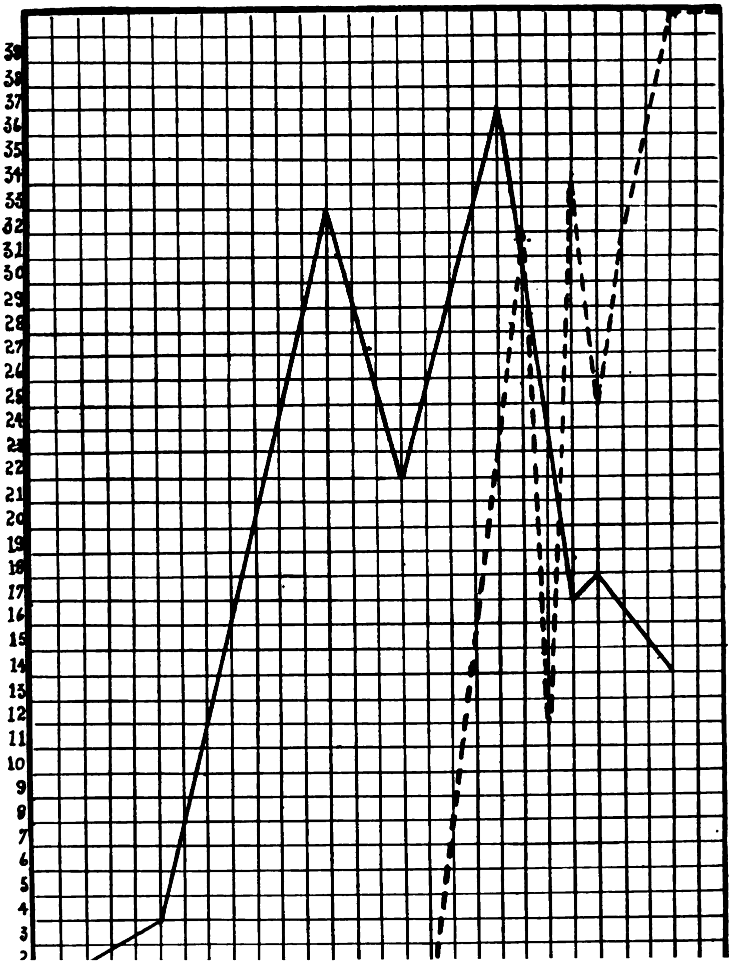


Fig. 17. Larvae of the Bull Pine Sawfly which have died of bacterial disease.

ARTIFICIAL MEANS OF CONTROL

That outbreaks of this sawfly may become exceedingly serious is indicated by the fact that in Germany whole forests of pine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and fir trees, sometimes involving thousands of acres, have been destroyed by closely related species of similar habits. But the above summary seems to clearly indicate that this outbreak of the Bull Pine Sawfly is being rapidly brought under control by the natural enemies of that insect, especially by the ichneumonid and tachinid parasites. The probabilities are that the affected area will not be further extended and that the injury will distinctly abate in intensity during the next season or two. This is particularly fortunate, for no adequate artificial means of control have as yet been suggested. Of course the larvae could readily be destroyed by spraying the trees with arsenical poisons or possibly even with hellebore, as has been recommended for other related defoliators of conifers, but on considering the powerful apparatus necessary to reach the tops of these tall pines and the amount of material and labor necessary to protect even a small area, obviously this standard means of controlling such insect defoliators becomes at once impractical because of the extensive cost. No practical means of gathering or destroying the cocoons has as yet suggested itself. A clearing up or burning over of the grass and fallen needles in the fall would control but partially, as this species, unlike *D. abietis* and *D. abboti,* seems to spin its cocoons mostly in the soil where they would be out of the reach of fire; nor would soil cultivation solve the problem, for the larvae seem to survive in their cocoons almost equally well whether buried in the ground or more or less exposed on the surface of the ground. It is possible, however, that in the event of the increase and spread of the outbreak some useful control measure can be devised.

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SPRAYING FOR THE MELON APHIS

BY MYRON H SWENK

EXTENT OF INJURY BY THE MELON APHIS IN NEBRASKA

Without question the most injurious insect pest of the cucumber and melon plants in Nebraska is the aphis or plant louse which attacks and destroys these vines. For many years past this insect has annually greatly curtailed the crop of pickles and melons in many sections of the state, especially eastwardly, and the damage seems to be increasing in intensity from season to season. As far back as 1892 a pickle company of Omaha which had been growing between 30,000 and 50,000 bushels of cucumbers a year, together with several hundred farmers in the same vicinity also growing that vegetable for the company, lost two-thirds of the crop thru the ravages of this aphis, while the following year one-half the crop was lost from the same cause. That such intense injury has not abated is shown by the accompanying map, which designates the localities from

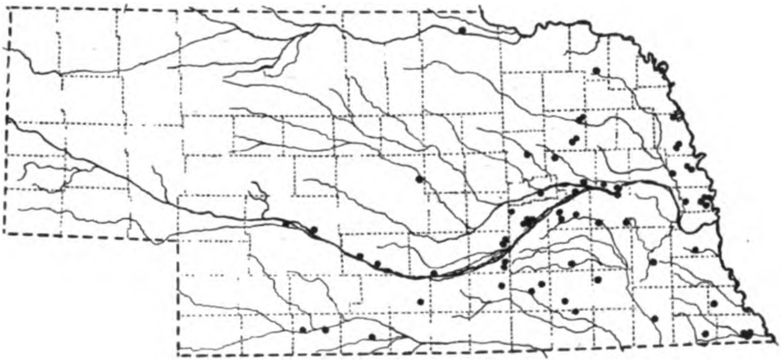


Fig. 1. Localities from which reports of serious losses by the Melon Aphis were received during 1908-1910, inclusive.

which the Experiment Staton has received reports of serious losses caused by the melon aphis during the past three seasons (1908-1910) in which this pest has been under special investigation. Most of these reports complain of severe damage or total loss of crop, and while some of them involve only small truck patches, in many other cases the farmer, truck gardener, or seedsman is growing these vegetables upon a more or less extensive commercial scale, and in such instances the individual losses amount to anywhere from one or two hundred to over a thousand dollars. These, taken together with the destruction of many thousands of vines in the small home truck patches of our farmers and townsmen alike which of course have not come to our notice, certainly must aggregate a loss of thousands of dollars annually. In some localities the growing of melons and cucumbers has been practically abandoned because of the destructiveness of this pest and the poor success which has attended the efforts of the growers at fighting it, even in localities where formerly over a hundred dollars' worth of melons per acre had commonly been grown. The same sort of condition seems to prevail in the states to the south of us; in fact the area from Nebraska to Texas is apparently the center of this insect's injury to cucurbitaceous crops.

NATURE OF THE INJURY

The melon aphis, like all other aphids or plant lice, sucks the juices of the plants by means of its tiny beak and by thus draining the leaves of their sap causes them to die. The aphids collect on the under surface of the leaves of the affected plant, and by virtue of their prodigious powers of increase soon have an enormous number of individuals all sucking the sap and thereby

color of the aphids themselves, gives a characteristic appearance to the lower surface of the infested leaves. In cases of severe infestation, and under normal conditions any infestation at all soon becomes a severe one, the entire leaf surface of the plant is simultaneously attacked and in a very few days the vine wilts and dies down. Whole fields are frequently thus destroyed within a week. Cucumbers seem distinctly more susceptible to early injury by this aphis than are melons, and also their foliage

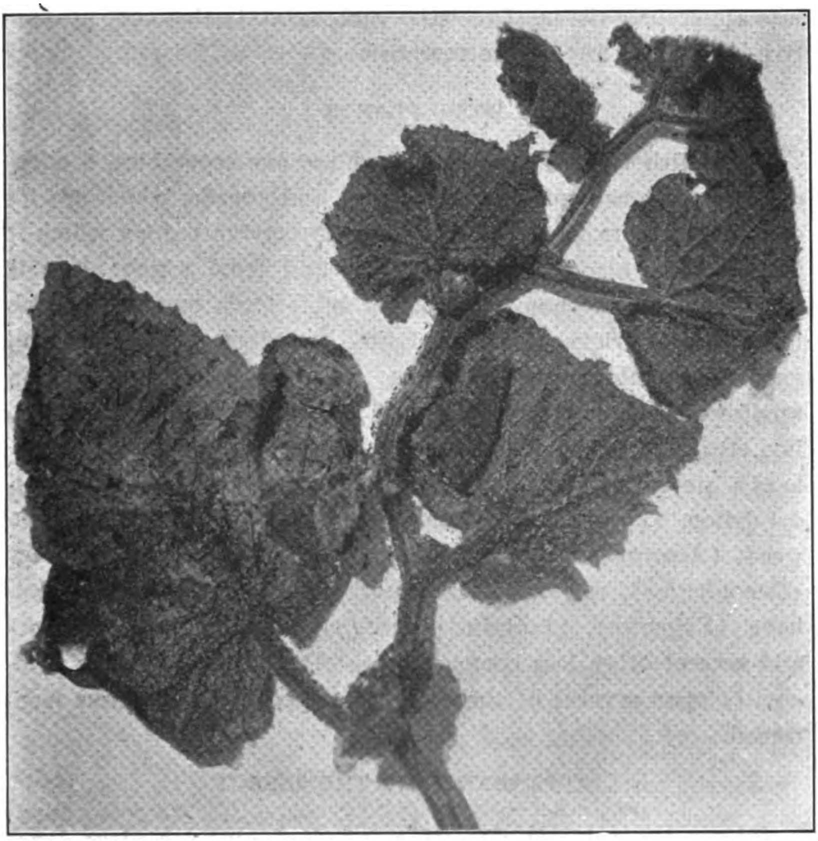


Fig. 2. Characteristic colony of Melon Aphis together with their shed skins on under side of cucumber leaves.

seems more easily injured by strong washes than are the melon leaves. Of the cucumber varieties which we worked with we found the Green Prolific was usually the most heavily infested, while the Early White Spined was next, yet the latter variety was apparently the most resistive and certainly the most productive of fruit of any of the varieties.

FOOD PLANTS

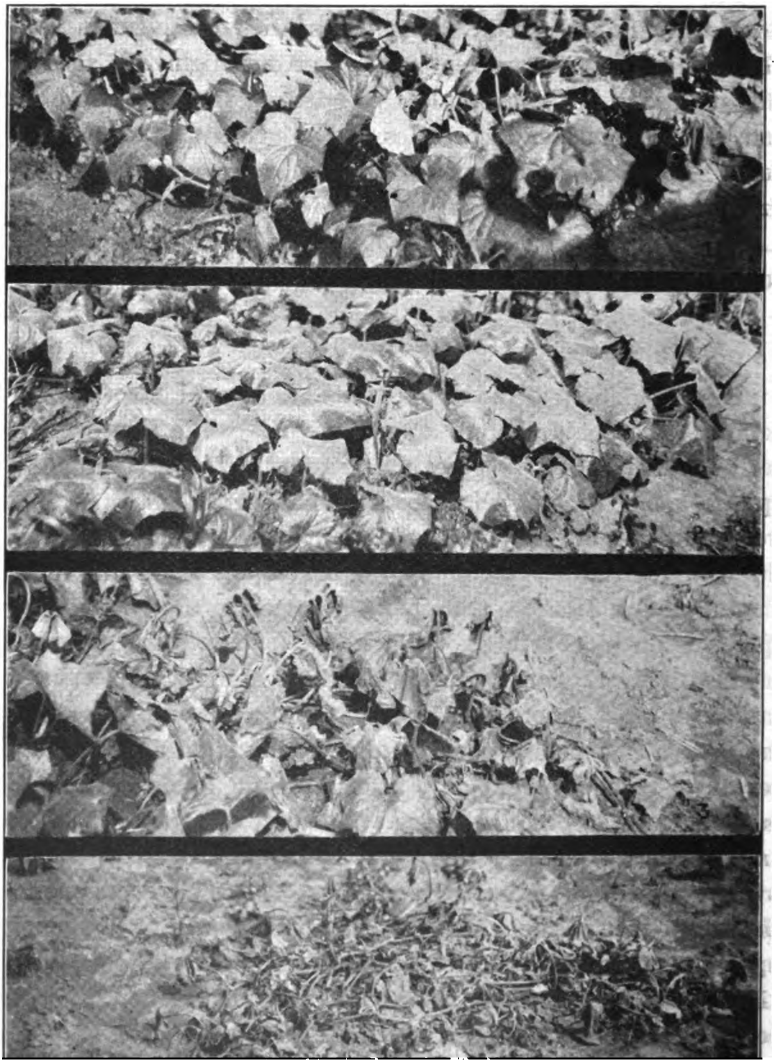
In addition to the various cucurbitaceous vegetables, *i. e.* cucumbers, melons, squashes, pumpkins, and gourds, which are its chief host plants, along with cotton (*Gossypium*) upon which it is sometimes also severely injurious and from which plant it derives its specific name, the melon aphis feeds upon an exceedingly large variety of other plants, including several common garden vegetables such as beets, tomatoes, asparagus, etc., a number of ornamental plants such as hydrangea, lilies, begonia, ivy, etc., and a long list of common weeds. These include shepherd's purse (*Bursa*), milkweed (*Asclepias*), dock (*Rumex*), dandelion (*Taraxacum*), lamb's-quarter (*Chenopodium*), pigweed (*Amaranthus*), peppergrass (*Lepidium*), morning-glory (*Convolvulus*), ragweed (*Ambrosia*), burdock (*Arctium*), fleabane (*Erigeron*), plantain (*Plantago*), jimsonweed (*Datura*) and several other less common ones. It probably winters principally upon several of these plants, especially those first mentioned.

APPEARANCE OF THE INSECT

The melon aphis is a small, soft-bodied, sluggish plant louse ranging from one-twentieth to nearly one-twelfth of an inch long and in the winged form with an expanse of one-fifth to one-fourth of an inch. The color is variable but a colony of this species may usually be recognized thru this very fact, there being nearly all variations of color within one colony from uniform pale green thru various degrees of mottling to a pale yellow or to almost black. This species has been much confused with other closely allied and exceedingly similar species of the genus *Aphis.* The dark individuals are very dark green, not highly polished and almost always are more or less mottled on the abdomen above, and the antennae and cornicles are relatively slender. It requires, however, in many cases a critical comparison to distinguish the melon aphis from some of its congeners, such as *A. medicaginis* and *A. carbocolor,* especially as these occur frequently upon the same food plants.

LIFE-HISTORY

The life-history of the melon aphis is not yet known in all its details. The aphids appear upon the vines while the latter are yet quite small and just beginning to run, the first aphids to appear being winged females, and they probably fly in from weeds or other alternate food plants upon which they have spent the winter. In 1909 we found the first aphis upon our experimental plat on June 24, and upon the same day also found young aphids upon older vines. Cool, rainy springs seem greatly to enhance a rapid multiplication of these aphids. After having gained a start upon the plants, the aphids reproduce very rapidly, each female producing alive from six to a dozen young per day. In about eight days after birth the aphis is adult and is itself ready to produce young. This sort of reproduction goes on thruout the summer and early fall, and from time to time winged individuals are produced, these becoming commonest in the latter part of the summer. The aphids continue abundantly upon the cucumber and melon plants until the vines have been killed by the fall frosts, and in early September they begin dispersing, probably to other vegetation. We are not sure just where they go or how they pass the winter in all cases, but apparently they hibernate more or less actively upon various plants. In Colorado these aphids have been followed upon out-of-door plants such as shepherd's purse thru the winter for two



seasons and part of a third without finding either males, egg-laying females, or eggs, and it seems quite likely that this species has no sexual forms or eggs, at least in some localities. We have never found them in Nebraska.

NATURAL ENEMIES

The melon aphis has a large number of natural enemies, including principally internal hymenopterous parasites and predaceous ladybird beetles and larvae, syrphus fly larvae and *Chrysopa* larvae. These find a generous food supply when the aphis increases in numbers, and sometimes gain at least a partial control of the aphids and save a part of the crop. Of them all, the ladybird beetles and their larvae are probably the most valuable and effective. Several species are concerned in this good work, but in Nebraska the convergent ladybird (*Hippodamia convergens*) is more abundant and does more good than all the other species combined. The small hymenopterous parasites are also exceedingly valuable, and sometimes rapidly reduce an abundance of these aphids until they are practically exterminated in that particular infestation. Thus on July 1, 1910, we found *Aphis gossypii* abundant upon a patch of our common milkweed (*Asclepias syriaca*), but it was heavily parasitized by a small Braconid, presumably a species of *Lysiphlebus*. By July 19 the parasite had completely exterminated the aphids upon these plants, a most careful search failing to reveal a single living aphis where about three weeks before they had been flourishing. In our experimental plats during latter July and August the influence of these parasites as well as that of the ladybirds was very obvious, and they were practically in control of the situation during the latter part of the season. The larva of the syrphus fly *Allograpta obliqua* is the most abundant and useful of the four species of syrphus flies attacking the melon aphis in Nebraska, and did very good work in our fields. Of the *Chrysopas* in this state, the larvae of *C. oculata, C. nigricornis* and probably other species are exceedingly valuable enemies of the melon aphis, occurring in large numbers wherever these tiny pests abound and feeding upon them voraciously.

CONTROL OF THE MELON APHIS

There is no avoiding the fact that in this aphis we have a pest hard to deal with and one which requires a great deal of vigilance and careful work to control. Artificial methods of treatment fall under two general classes—fumigation and spraying. Fumigation includes the use of bisulphid of carbon and tobacco fumigants. While we have done some work with the control of this aphis thru fumigation, our spraying experiments have been much more complete and successful and are discussed in some detail on the following pages. It is important that the treatment should be applied at the first indication of the occurrence of wingless aphids on the vines, before the insects have had time to cause any obvious wilting or curling up of the

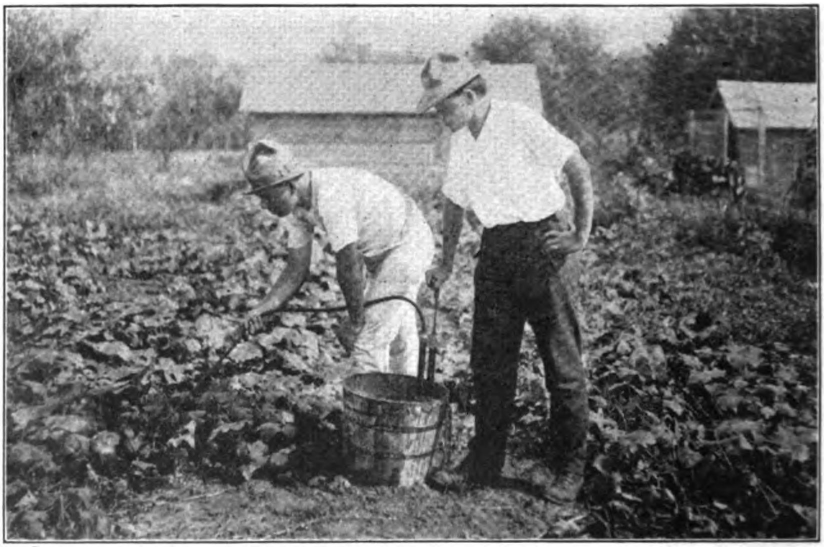


Fig. 4. Spraying for Melon Aphis, season of 1909.

leaves. In order to do this the vines must be gone over frequently and the lower side of the leaves examined thoroly. In spraying, the application of the wash should be done either with the undersprayer, or by very carefully lifting back the vines, spraying the under surface of the leaves and then replacing them in their original position. Badly curled leaves should be opened by hand and the under surface drenched with the wash. As an undersprayer we used a piece of gas pipe with one end bent at the proper angle and a Vermorel nozzle attached at this end, as shown in the illustrations. A bucket pump was used in applying the wash, and two men usually worked together, one to operate the pump and the other to direct the spray

SPRAYING EXPERIMENTS

During the past three summers, 1908 to 1910, the experiments which we carried on were to determine, if possible, some wash which would prove effective against the melon aphis as a contact insecticide, and yet would not injure the very tender foliage of the cucumber and melon plants. At the time of our taking up this line of experimentation, the commonly recommended treatment for this pest was a thoro spraying of the young plants with kerosene emulsion when the aphis first appeared on the vines, and the efficiency of this remedy was tested first.

On June 25, 1908, a severely infested patch of muskmelon and cucumber vines was thoroly sprayed with a carefully prepared emulsion containing 8 per cent. of kerosene; the aphids were killed and also the vines. On July 27 a moderately infested patch of muskmelons was sprayed with kerosene emulsion of varying strengths, containing 8 per cent., 6 per cent., 5 per cent., and 4 per cent. of kerosene, and two days later all of the sprayed plants were dead, even those sprayed only with the 4 per cent. strength. Subsequent tests demonstrated convincingly that in order to kill these hardy and resistive aphids the kerosene emulsion must be made so strong that the exceedingly tender cucurbit leaves are invariably badly burned, thereby either killing the plant outright or greatly injuring it, and that for this reason the treatment was too harmful and unreliable to warrant its continued recommendation as a remedy for the melon aphis.

After the abandonment of the attempts to successfully combat the aphis with kerosene emulsion an effort was made to discover some other contact insecticide which would accomplish the desired result. Five washes were prepared, some of which had already been mentioned in various publications as useful against this insect, namely a soap and tobacco wash, a resin-soda-fish-oil wash, a soap-and-fish-oil wash, a resin-soda wash and a tobacco decoction. These were prepared according to the following formulae:

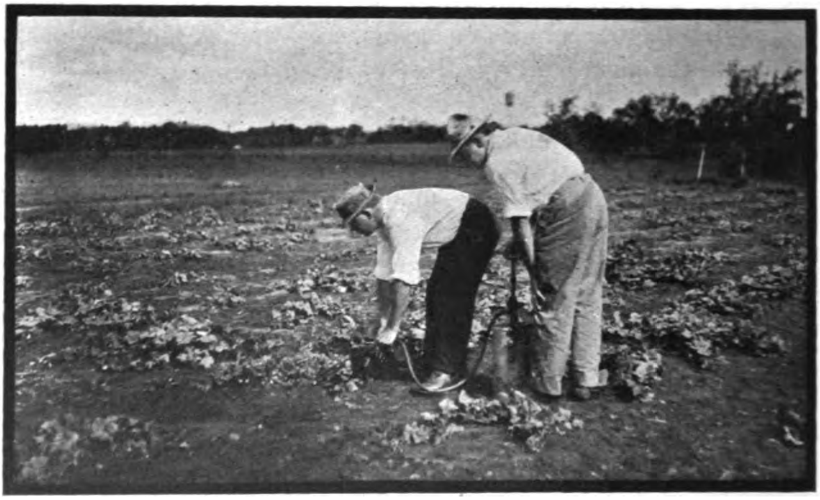


Fig. 5. Spraying for the Melon Aphis, season of 1910.

1. *Soap-and-tobacco wash.*—Dissolved two and one-half pounds of soap in one gallon of water and added one quart of strong tobacco decoction and boiled together five minutes. Diluted to make five gallons.

2. *Resin-soda-fish-oil wash.*—Dissolved one-fourth pound of

caustic soda in one gallon of water. Removed half of the solution and added one pound of resin to it. When resin was thoroly dissolved added one-third pint of fish-oil and stirred thoroly. Added remaining half of soda solution and boiled one hour. Diluted to make five gallons.

3. *Soap-and-fish-oil wash.*—Dissolved one-third pound of laundry soap in one gallon of water and when boiling added one-half pint of fish-oil. Diluted to make five gallons.

4. *Resin-soda wash.*—Dissolved one-fourth pound of caustic soda in one quart of water and added three-fourths pound of resin to the solution and boiled one hour. Diluted to make five gallons.

5. *Tobacco decoction wash.*—Soaked tobacco stems in water and then steeped for one hour, forming a very strong decoction. Diluted to color of weak coffee and sprayed.

On July 29, 1909, a field of muskmelons and cucumbers was sprayed with these five washes. The variety of muskmelon treated was the Rocky Ford Netted Gem, while the cucumber varieties were Early Frame, Early Green Cluster, Early White Spined, Green Prolific and New Siberian. The day was hot and bright with a temperature of 95 degrees and much humidity. The spraying was done in the morning and early afternoon, the washes all being applied as underspray. The results are shown in tabular form below:

TABLE 1.—*Results of spraying with several contact insecticides.*

Spray used	Condition July 29, just before spraying, 8:00 a. m.	Condition July 30, 17-23 hours after spraying.	Condition July 30, 22-27 hours after spraying.	Condition July 31, 2 days after spraying.	Condition August 2, 4 days after spraying.
Soap and tobacco wash	Medium to heavy infestation; Early White Spined and Early Frame most infested; plants not wilted.	Aphids mostly dead, a few alive; plants apparently unaffected.	Aphids all dead; plants unaffected.	A few living aphids; probably new ones; a few vines show some burning injury.	Best results of the five washes; aphids killed and plants not seriously injured.
Resin-soda-fish-oil wash	Light to medium infestation; plants not wilted.	Aphids partially dead but many alive; plants apparently unaffected.	Aphids about all dead; plants unaffected.	Aphids mostly dead; plants not seriously injured.	Aphids mostly killed but plants somewhat injured by wash.
Soap and fish-oil wash	Medium to heavy infestation, especially on Green Prolific; plants not wilted.	Aphids mostly dead; plants apparently not injured.	Aphids all dead; plants quite badly burned.	A few living aphids, probably new ones; one vine dead, rest in only fair condition.	Aphids killed but plants badly injured by the wash.
Resin-soda wash	Light to heavy infestation; plants not wilted.	Very few aphids dead; plants apparently unaffected.	Very few aphids dead; plants not obviously affected.	Very few aphids dead; plants unaffected.	Very little effect on the aphids.
Tobacco decoction wash	Light to heavy infestation, especially heavy on Green Prolific; plants not wilted.	Few or no aphids dead; plants apparently unaffected.	Very few aphids killed; plants unaffected.	Plenty of aphids; vines in good condition.	Little or no mortality to aphids.

From the foregoing it will readily be seen that the soap-and-soap-and-tobacco wash. The soap-and-fish-oil wash burned the foliage so badly that it was at once discarded, while the resin-soda wash and tobacco decoction were ineffective, the latter probably because too weak. The soap-and-tobacco wash being the most promising one, it was experimented with more extensively.

In making up the next wash, the strength of the tobacco decoction was decreased and was used when of a pale brown color and much weaker, but a gallon instead of a quart was used in each five gallons of the wash. The decoction was made by soaking stems ten days in water and then draining off the water and steeping the stems in fresh water for a quarter of an hour. The same quantity of soap was used as in the preceding soap-and-tobacco wash formula and the same dilution was practiced. The spraying was done August 4, 1909, a bright, very hot day with a slight south breeze.

The application was made in two ways. Some hills were treated by the ordinary use of the undersprayer while in others the vines were carefully lifted back so as to expose the under surface of the leaves, which were then drenched with the wash. In all spraying operations, care was taken not to employ too great a force, otherwise the tender epidermis of the leaves would have been seriously injured. Also great care was taken in lifting back the vines so as not to break or tear them. One man did the vine lifting and spraying while the other man operated the pump and replenished the wash as exhausted.

The wash was applied to fifteen hills of cucumbers and fifteen hills of melons. In this field altho the cucumbers and melons were equally heavily affected, as usual the melons were more resistive and in better condition than the cucumbers. In the higher and drier portions of the field the effect of the aphid attack was conspicuously more in evidence, some of the hills being in a dying condition. The results of this spraying are shown in tabular form below:

TABLE 2.—*Results of spraying with soap and weak tobacco wash.*

No. of hill	Cucumbers		Melons	
	Condition before spraying, August 4, 10:00 a. m.	Condition 24 hours after spraying, August 5.	Condition before spraying, August 4, 10:00 a. m.	Condition 24 hours after spraying, August 5.
1	Medium infestation; plant in good condition.	Aphids mostly killed; plant in good condition showing no spray injury.	Very heavily infested; plant in good condition.	Aphids dead where wash came in contact with them; a very few seemed to have escaped the wash; plant in good condition, one runner injured in turning vines.
2	Heavy infestation; plant in dying condition.	Aphids killed; plant almost dead.	Very heavily infested; plant in good condition.	Aphids mostly dead but some leaves had a few live ones on a part of the leaf; a few live winged aphids; plant in good condition.
3	Heavy infestation; plant in dying condition.	Aphids about all dead; plant nearly dead.	Very heavily infested; plant in good condition.	Aphids mostly dead but some live wingless and winged ones present; plant in same condition as yesterday.
4	Heavy infestation; plant in very poor condition, dead in center.	Aphids mostly dead but some leaves with living ones; plant as yesterday.	Very heavily infested; plant in good condition.	Aphids mostly dead; plant in good condition.
5	Heavy infestation; plant as hill 4.	Aphids all killed; plant nearly all dead.	Fairly heavy infestation; plant in very good condition.	Most of leaves with aphids killed, some leaves in center of hill with live aphids, apparently unsprayed; plant in

TABLE 2.—*Results of spraying with soap and weak tobacco wash —Concluded.*

No. of hill	Condition before spraying, August 4, 10:00 a. m.	Condition 24 hours after spraying, August 5.	Condition before spraying, August 4, 10:00 a. m.	Condition 24 hours after spraying, August 5.
7	Heavy infestation; plant small and in very poor condition.	Three or four leaves apparently unsprayed, with live aphids; plant in same condition as when sprayed.	Same as two preceding hills.	Aphids dead where wash came in contact with them, some folded leaf corners with live ones; plant in fair condition. One runner broken off in handling.
8	Heavy infestation; plant nearly dead.	Aphids mostly killed; plant in very poor condition.	Fairly heavy infestation; plant leaves burned with soap and fish-oil wash previously applied.	Aphids mostly killed; plant as yesterday.
9	Very heavy infestation; plant in dying condition.	Aphids mostly killed.	Heavy infestation; plant severely affected.	Aphids 85 per cent. killed but many live winged ones; one runner broken off in turning; condition of plant fair.
10	Same as hill 9.	A few live wingless aphids and many winged ones.	Very heavy infestation; plant severely affected.	Aphids mostly all dead; 98 per cent. killed; plant with a few dead leaves.
11	Same as hill 9.	Aphids mostly dead; plant dying.	Same as hill 10.	Aphids mostly killed; plant in same condition as yesterday.
12	Same as hill 9.	Aphids abund'nt, only 40 per cent. killed; plant half dead.	Very heavy infestation; plant very severely affected.	Aphids mostly dead; condition of plant poor.
13	Same as hill 9.	Plant dead.	Same as hill 12.	Aphids killed, 90-95 per cent. dead; condition of plant poor.
14	Same as hill 9.	Leaves with aphids mostly killed but live ones in spots.	Very heavy infestation; plant dying.	Aphids killed; plant about dead.
15	Same as hill 9.	Same as preceding hill.	Same as hill 14.	Aphids killed; plant about dead.

In the above experiment the object was not to save the plants, since many of them, especially of the cucumbers, were in a dying condition when sprayed, but rather was to determine the mortality this wash would have upon the aphids. The results seem to show that wherever the wash came in direct contact with the insects their death resulted, but in the operation occasional folded portions of leaves would be missed and these invariably harbored living wingless aphids. There being unsprayed infested plants close at hand the presence of many winged aphids twenty-four hours after spraying is easy to account for, these having simply flown in from the adjacent hills. On the whole the results were not quite so satisfactory as with the previous soap-and-tobacco spraying, tho nearly so, as the weaker condition of the tobacco decoction was largely offset by the greater quantity used.

It was next determined to note the effect of decreasing the soap and increasing the tobacco decoction, and accordingly a wash was made up of one and one-eighth pounds of soap (a little less than one-half the amount previously used) with one-half gallon of strong tobacco decoction (twice the amount previously used) added to each five gallons of the wash. Three rows of cucumbers were sprayed with this wash, there being twenty hills in each row. The wash was applied on the afternoon of August 6, and on the morning of August 7, 1909, row 1 being sprayed by lifting back the vines while rows 2 and 3 were undersprayed. The results of this spraying are shown in tabular form below:

TABLE 3.—*Results of spraying with soap and strong tobacco wash.*

No. of row	Variety	Condition before spraying, August 6 and 7.	Condition 3 days after spraying, August 9.
1	Early White Spined	Medium to heavy infestation.	Most of aphids killed; hills not much reinfested; vines in fair to poor condition.
2	Improved Long Green	Medium to heavy infestation; row in fair to good condition except three hills in middle.	Aphids mostly all killed; vines near middle of field about dead, rest in fair condition.
3	Early Frame	Medium to heavy infestation; row in good condition except three hills which were pulled out.	Aphids 90 per cent. dead; row in fair condition except two hills which are dead.

It seemed that the rows treated by underspraying had at the end of three days a somewhat better color and more blossoms than the row sprayed by lifting back the runners, altho the difference was not great, and possibly is offset by the greater ease of application in the lifting back method. The mortality to the aphids by the use of this wash seemed to average about as in the preceding soap-and-tobacco washes.

At the same time, in order to determine if a soap-and-tobacco wash much weaker in soap would yet kill the aphids, the soap was decreased to five-sixths of a pound while nearly one-half gallon of strong tobacco decoction was used to each five gallons of spray. At the same time the effects of a wash made of a patent sulpho-tobacco soap (Larkins') and whale-oil soap was tested, the former by dissolving four ounces of the soap in two gallons of water (as per directions), the latter by dissolving one-half pound of soap in ten gallons of water and applying warm. This was applied on the afternoon of August 7. The undersprayer was used in all cases. The results of the use of these sprays are shown in tabular form below:

TABLE 4.—*Results of spraying with three soap washes.*

Spray used	Condition August 7, just before spraying; 2:00 p. m.	Condition August 9, 2 days after spraying; 11:00 a. m.
1. Soap and tobacco wash	Infestation heavy in spots.	Aphids killed; vines not obviously injured by wash.
2. Sulpho-tobacco soap	Infestation light.	Aphids apparently all killed; vines unhurt by spray.
3. Whale-oil soap	Infestation medium to heavy.	Aphids not extensively killed; vines somewhat injured.

From the foregoing it is seen that the whale-oil soap is not sufficiently effective to be of value against the melon aphis, thus falling into the category with the resin-soda wash and the pure tobacco decoction used in the first experiment. The sulpho-tobacco soap is effective, but used according to directions it costs nearly 7 cents per hill, which renders it prohibitively expensive for any extended use. The soap-and-tobacco wash used with even less than a pound of soap is shown by the above spraying to be effective.

As a final test, two soap-and-tobacco washes of distinctly different strengths were applied to a patch of muskmelon plants, a stronger one using one and three-eighths pounds of soap and five-eighths of a gallon of strong tobacco decoction to each five gallons of wash, and a weaker one using only two-thirds of a pound of soap and three-eighths of a gallon of the decoction to each five gallons of wash. This was applied on August 8 as an underspray. On the next day, August 9, on the plants sprayed with the stronger wash the aphids were found to be dead and the foliage not distinctly injured, while the plants on which the weaker wash was used, tho likewise uninjured, had the aphids only temporarily paralyzed and they later recovered to a large extent.

Summarizing these experiments with the soap-and-tobacco washes it would seem that ordinarily prepared tobacco decoction alone is not satisfactorily effective, but that combined with soapsuds it does the work well. When but two-thirds of a pound of soap is used to each five gallons of wash the aphids are not likely to be killed outright in large numbers, but a slight increase to five-eighths of a pound may accomplish their destruction. A strength of one and one-eighth pounds of soap is satisfactorily effective, while that of two and one-half pounds of soap is entirely effective tho perhaps unnecessarily strong. In no case should less than a quart of strong tobacco decoction be used and if the decoction seems weak this may be increased to a gallon. From the foregoing it can be reasonably concluded that a wash made up of one and one-half pounds of soap dissolved in one-half gallon of water with one-half gallon of strong tobacco decoction added and diluted to make five gallons will prove an effective wash in controlling the melon aphis and will not injure to any serious extent the foliage of either muskmelons or cucumbers.

On June 10, 1910, a space of 150x100 feet was planted to Early White Spined cucumbers. They were planted in thirteen rows, the first six rows, counting from the east, having thirty hills each, the next seven having twenty-six hills each, making in all 362 hills. These plants became seriously infested with the melon aphis in latter June and were sprayed with a dilution of the commercial tobacco extract "Black Leaf" June 25 and 27. "Black Leaf" is simply a tobacco extract containing 2.7 per cent. of nicotine, and retails at $1.00 per gallon. Three strengths were used in this experiment, the extract being diluted with 70, 50, and 25 parts of water on different hills. The results of this experiment are shown in the following table:

TABLE 5.—*Results of first spraying with "Black Leaf."*

No. of row	Strength used	Sprayed	Examined	Effect of spraying
1	1-70	June 25	June 29	90 per cent. free from aphids; plants thrifty.
2	1-70	"	"	Very few aphids found.
3	1-50	June 27	"	No aphids present.
4	1-50	"	"	97 per cent. free from aphids; very few present.
5	1-50	"	"	No aphids. Plants small and backward.
6	1-50	"	"	No aphids found.
7	1-50	"	"	Very few aphids present, 97 per cent. free.
8	1-50	"	"	No aphids; plants small.
9	1-50	"	"	No living aphids; plants small.
10	1-50	"	"	A very few aphids; 95 per cent. free.
11	1-50	"	"	Free from aphids; a few striped beetles present.
12	1-50	"	"	Very few aphids; 97 per cent. free.
13 north half	1-50	"	"	No aphids; plants thrifty.
13 south half	1-25	"	"	No aphids; plants thrifty.

The results seem to indicate that the one-to-fifty dilution was sufficiently more effective than the one-to-seventy wash to justify the use of the greater strength. The one-to-twenty-five to reproduce and restock the vines. By July 5, a week later, about one-half of the vines again had considerable numbers of aphids, and the plat was resprayed with a uniform strength of one part of "Black Leaf" to fifty parts of water. The results are shown in Table 6:

TABLE 6.—*Results of second spraying with "Black Leaf."*

No. row	Strength	Sprayed	Examined	Effect of spraying
1	1-50	July 5	July 8	The best results of any of the experiments. No living aphids whatever found, in a careful examination of the entire field. A heavy rain on July 7 had splashed underside of leaves with a thick coating of dirt, and leaves showed some hail injury. A few striped beetles (*Diabrotica*) were present.
2	"	"	"	
3	"	"	"	
4	"	"	"	
5	"	"	"	
6	"	"	"	
7	"	"	"	
8	"	"	"	
9	"	"	"	
10	"	"	"	
11	"	July 6	"	
12	"	"	"	
13	"	"	"	

Following the spraying on July 9, rows 11, 12, and 13 showed some *Diabrotica* injury .and these beetles were then largely picked off and destroyed, but no living aphids were found. On July 11, the first living aphids were found in the field, ten out of thirty-five vines examined being infested with winged females, one to four on each infested vine. July 14 a few young aphids were in evidence but not enough to spray for. July 22 the beetles had become abundant, and thoroly air-slacked lime was sprinkled over the plants to repel them. July 25 the beetles had practically deserted the field, being very few in number, but by August 1 were again abundant, five to ten of them on each hill, and the lime treatment was repeated, dusting each hill thoroly, especially about the bases of each plant, and this proved adequate protection. By August 10 the plants began blossoming profusely and small cucumbers started setting. Cucumbers continued forming thru August and September and until killing frosts in October. During August the aphids reappeared somewhat, but numbers of *Hippodamia convergens* swarmed over the vines and the *Lysiphlebus* parasite was very active so that the aphids did not become abundant enough to require spraying.

COMPARATIVE COST OF VARIOUS WASHES

The cost of the various soap-and-tobacco washes used in these experiments varied of course according to the amount of soap and tobacco and the length of the boiling period (an alcohol burner being used for this purpose) while the amount used varied with the size of the vines constituting the hills. However, a few comparisons can be made. The soap and weak tobacco wash required fifteen gallons to spray thirty hills, averaging one-half gallon to the hill and requiring two hours for two men or about four minutes per hill, the wash itself costing approximately two cents per hill. The soap and strong tobacco wash required forty gallons to spray sixty hills, thus averaging two-thirds of a gallon per hill, and nine hours for two men, or about nine minutes per hill, to prepare and apply it, both operations being done with great care and thoroness, while the cost of the wash approximated one cent per hill. In the first spraying with "Black Leaf" sixty-one gallons of wash was used on 362 hills, making about one-sixth of a gallon (.16) per hill, this requiring about eight and one-half pints of the extract, costing about $1.06 or about three mills (.029 cents) per hill and six hours' time for two men or about one minute per hill to apply it (no preparation of material being necessary), the plants being smaller and younger as compared with those sprayed the preceding season with the soap-and-tobacco wash; in the second spraying the quantity of wash and time required (5½ hours) for the same patch was approximately the same, tho the uniformly stronger solution (1-50) brought the cost up to $1.20, or a trifle less than one-third of a cent per hill. On larger plants the amount of wash used might easily have been doubled and the cost approach closely one cent per hill. Nevertheless, it seems that the "Black Leaf" is the cheapest effective spraying material we have tried and also has the advantages of being practically ready to use, of uniform and definite strength and somewhat easier of application because of its greater thinness.

CULTURAL METHODS

It should also be mentioned that clean culture is important in fighting the melon aphis. As soon as the crop is gathered, the vines should be immediately gathered together and burned, in this way destroying the aphids which are harboring thereon and preventing their dispersing to other plants to hibernate and form a source of infestation in the following spring. All weeds in the vicinity, especially those kinds mentioned under the list of food plants, should so far as practicable be destroyed during the summer and thus provide a scarcity of alternate food plants upon which the aphids may hibernate. Fall plowing also should not be omitted, as it has its beneficial effects, both against this and other insect pests. These general measures, together with spraying at the proper time, either with the recommended soap-and-tobacco wash or "Black Leaf" one to fifty, will enable the growth of profitable cucurbit crops in spite of the melon aphis.

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GENETIC CORRELATION AND SPURIOUS ALLELOMORPHISM IN MAIZE[1]

BY R. A. EMERSON

COLOR CORRELATIONS IN GENERAL

Some of the best known cases of supposed correlation are those in which there is similar coloration of distinct parts of plants. Common examples are colored flowers associated with colored seed-coats in beans, sweet peas, etc., and white (colorless) flowers with white (colorless) seed-coats. Bateson[2] has pointed out that in such cases the two features may be supposed to depend on one allelomorph rather than on two correlated ones and that in order "to prove the existence of complete coupling it would be necessary to show that features *elsewhere known to depend on separate allelomorphs* could on occasion be linked in a complete union." That such cases as these have not been shown to depend on two or more correlated genes does not of course prove that they are one allelomorph. In this connection it should be noted that it is often very difficult to tell whether characters are genetically correlated or not. And this difficulty is often overlooked. For instance, Morgan,[3] in his recent discussion of chromosomes and heredity plainly indicated his belief that few characters are genetically correlated, as is shown by the following quotation:

> Since the number of chomosomes is relatively small and the characters of the individual are very numerous, it follows on the theory that many characters must be contained in the same chromosome. Consequently many characters must Mendelize together. Do the facts con-

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[1] Read before the Ithaca meeting of the American Society of Naturalists, December 30, 1910.

[2] Bateson, W. Mendel's Prin. Heredity, pp. 158-9 (1909).

[3] Morgan, T. H. Amer. Nat. 44 : 467, 468.

> form to this requisite of the hypothesis? It seems to me that they do not. A few characters, it is true, seem to go together, but their number is small, and it is by no means evident that their combination is due to a common chromosome. It is true that in no one species do we know much concerning the behavior of many characters, but so far as we do know them, there is no evidence that they Mendelize in groups commensurate with the number of chromosomes. In two cases, in fact, viz., in *Pisum* and in *Antirrhinum*, it appears that the number of the characters that have been shown to Mendelize separately is greater than the number of their chromosomes.

Spillman's way of "eluding this objection to the chromosome view," as Morgan terms it, while all right as far as it goes, is only half what may be said. Spillman recognized the fact that to disprove the assumed connection between characters and chromosomes there must be shown to be present in the same individual more separately inherited dominant characters than there are chromosomes. As a matter of fact, *more* dominant characters than there are chromosomes might be present and we even then be unaware of any coupling of genes, (any Mendelizing in groups). In order to exhibit Mendelian behavior with respect to any character whatever, the two parents of a cross must differ in the character concerned. Similarly, unless the two parents *differ* by *more* characters than the gametic number of chromosomes, genetic correlation might not be apparent even tho many more characters than chromosomes were *present*. That is to say, we might not be able to see any correlation even tho it were perfect with respect to many characters.

We should not be surprised then to find that many characters dence of it and in fact its possibility never occurred to me. When, therefore, after some years of experimentation, I procured a commercial variety that had "golden" leaves as well as yellow pods, crossed it with a green-podded green-leaved sort, and obtained green-podded green-leaved F_1 plants, I fully expected to get the four presumably possible types in F_2. There were, however, among several hundred individuals (1404 to be exact) only two types, namely, green-leaved, green-podded plants and yellow-leaved and yellow-podded ones, about three of the former to one of the latter (observed 1070: 334, expected 1053: 351).

Maize affords some of the clearest cases of genetic correlation and yet one might cross many races without detecting them. If one crossed a race having red cobs, red pericarp, red silks, and reddish husks with one having no red in these parts and in F_2 secured on the average three plants with red cobs, red silks, red grains and somewhat reddish husks to one with white cobs, white (or greenish) silks, white grains, and white husks, he might well hesitate to pronounce the result a case of genetic correlation. How can he know that the production of red pigment in all these parts of the corn plant is not the result of a single gene? Or, if he had not made crosses similar to this but knew well many varieties of corn, he would be able to name sorts having red grains and red silks with white cobs, or white grains and red silks with red cobs, or again white grains and red silks with white cobs. This knowledge would certainly not lead him to suppose that colors of cobs, silks, pericarp, etc., are correlated in inheritance.

GENETIC CORRELATION IN MAIZE COLORS

Some knowledge of both these series of facts, namely, *first,* that color of cob, silk, pericarp, etc., behave as one unit in crosses when all are present in one parent and all absent from the other, and, *second,* that these same colors are frequently dissociated in various races, made corn seem to me one of the best subjects for the investigation of genetic correlations. Such data as I have been able to collect since I became interested in this question, I shall present here in some detail. I recognize the fragmentary nature of my records and the fact that in many individual cases the number of plants dealt with is too few to give the most reliable results. With reference to certain characters, however, I believe my data are sufficiently complete to make their meaning quite clear.

When this work with corn was begun a couple of years ago, I had few types that I knew to be pure. The first thing to do therefore was to self-pollinate a number of individuals of the various sorts on hand, to determine which were pure, and to isolate other pure strains with which to work later. The fact that many of the plants worked with the first year were heterozygous as shown by their progeny was an actual advantage. It put the work one year ahead of where it would have been now had I started with pure parents and crossed them the first year. In addition to the self-pollination work, crosses were made the first year with numerous individuals, some of which proved later to be pure with respect to certain characters and some of which were obviously heterozygous. The latter crosses are no less interesting and indeed no less valuable than the former.

In the tables below, the various colors (except anther colors) are those of the mature, dry parts. They are indicated as follows:

R = red that is evenly distributed over the part—"self" red. In the husks it is less intense than in the cob, pericarp, etc.

V = variegated color pattern. The only color observed in this pattern is red. It consists of irregular stripes. The pericarp of the grains is sometimes finely and closely striped thruout the ear, sometimes more coarsely and sparsely striped. Frequently whole grains or even large patches of grains are much darker or lighter than the other grains of the same ear, sometimes even being solid red or quite colorless. Rarely one ear is nearly solid red while another on the same plant has striped grains. Variegated cobs often show patches of red and white but sometimes appear fairly evenly light red owing to the fine, close striping of the "chaff."

Br = brown, a pericarp color rarely seen.

Lb = light brown, also a pericarp color.

W = white. It signifies a lack in the cob, pericarp, and husks of the colors here under consideration.

D = dark and refers to the color of the dry silks. They may have been either red or pink when fresh.

L = light silks (when dry). They are usually white or greenish when fresh.

Pk = pink anthers.

DP = dark purple—the dark bluish purple (nearly black) pigment of the husks, cobs, anthers, leaf sheaths, stalks, etc., of certain races of corn.

P = purplish—possibly merely a less intense development of the dark bluish purple.

PW = purplish white—a slight purplish tinge of the pericarp.

TABLE 1.—*Correlated colors in maize.*

Pistillate parent				F$_1$ from open-pollinated P$_1$						F$_2$ from self-pollinated F$_1$						
	Color of				Color of							Color of				
Plant No.	Cobs	Pericarp	Husks	Plant No.	Cobs	Pericarp	Husks	Silks	Anthers	Family No.	Frequency	Cobs	Pericarp	Husks	Silks	Anthers
$82_{(4)}$	...	R	...	$143_{(1)}$	R	R	...	...	...	349	17	R	R	...	..	......
											4	W	W	...	..	......
$47_{(6)}$	W	W	...	$156_{(1)}$	V	V	...	...	...	364	23	V	V	...	..	......
											8	W	W	...	..	......
$47_{(6)}$	W	W	...	$156_{(2)}$	V	V	...	...	...	365	16	V	V	...	..	......
											(2	R	R	...	..	...)[4]
											8	W	W	...	..	......
19	R	V	...	$19A_{(3)}$	R	R	...	...	...	293	45	R	R	...	..	......
											10	V	V	...	..	......
157	V	(V)R[5]	...	157 [illegible]	R	R	...	...	...	370	45	R	R	...	..	......
											12	V	V	...	..	......
21	R	R	...	$21_{(6)}$	R	R	...	...	...	315	37	R	R	R	..	......
											17	V	V	V	..	......
$22_{(14)}$	W	HR	...	$102_{(4)}$	R	R	...	...	...	152	22	R	R	...	..	......
											6	W	HR	...	..	......
$22_{(14)}$	W	HR	...	$102_{(8)}$	R	R	...	...	...	338	43	R	R	R	..	......
											14	W	HR	W	..	......
$22_{(12)}$	W	HR	...	$101_{(2)}$	R	R	...	...	...	335	92	R	R	R	..	......
											36	W	HR	W	..	......
146	W	Br	...	$146_{(12)}$	R	R	...	...	...	354	12	R	R	R	..	......
											4	W	Br	W	..	......
146	W	Br	...	$146_{(10)}$	R	R	...	...	...	358	18	R	R	R	.	......
											4	W	Br	W	..	......
146	W	Br	...	$146_{(7)}$	R	R	R	D	...	357	16	R	R	R	D	......
											7	W	W	W	L	......
											(1	W	Br	W	D	....)[6]
13E (A)	W	W	...	$225_{(1)}$	V	V	...	...	...	404	33	V	V	...	D	......
											11	W	W	...	L	......
$42_{(3)}$	R	R	...	$138_{(2)}$	R	R	...	D	...	346	90	R	R	R	D	......
											28	W	W	W	L	......
148	...	W	..	$148_{(1)}$	R	W	W	D	...	480	12	R	W	W	D	Pk
											5	W	W	W	L	Pk
271	DP	P	DP	$271_{(5)}$	DP	P	DP	D	DP	489	11	DP	P	DP	D	DP
											4	W	W	W	D	Pk
271	DP	P	DP	$271_{(9)}$	DP	P	DP	D	DP	496	30	DP	P	DP	D	DP
											13	W	W	W	D	Pk
											(3	P	PW	P	D	DP)[6]
											(1	P	PW	P	D	Pk)[7]
271	DP	P	DP	$271_{(8)}$	DP	P	DP	D	DP	492	45	DP	P	DP	D	DP
											8	P	PW	P	D	DP
271	DP	P	DP	$271_{(1)}$	P	PW	P	D	DP	491	55	P	PW	P	D	DP
											25	W	W	W	D	Pk
271	DP	P	DP	$271_{(7)}$	P	PW	P	D	DP	495	42	P	PW	P	D	DP
											16	W	W	W	D	Pk

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[4] These red ears are probably extreme, dark forms of the variegation. "Calico" corn commonly produces red ears—sometimes on the same plant with variegated ones.

[5] There were both red and variegated grains on the same ear; F$_1$ was grown from a red seed.

[6] "Off-type" plants—probably due to accidental crossing in F$_1$.

[7] No other plant of this type has been seen. If no mistake was made in recording the anther color, this record indicates a "break" in the correlation.

The staminate parents of the hybrids recorded in Table 1 were unknown, the pistillate parents having been neither self-pollinated nor cross-pollinated artificially. The F_1 plants were all carefully self-pollinated. Evidently the parents of these hybrids differed in from two to four color characters. In every case but four included in this table, only two types occurred in F_2. (The four exceptions are discussed in footnotes.) One type always had all the dominant colors of the parts in which the two types differed in color and the other type all the recessive colors. (See figures 1 and 2.) There was apparently an absolute correlation (presumably a genetic correlation) between

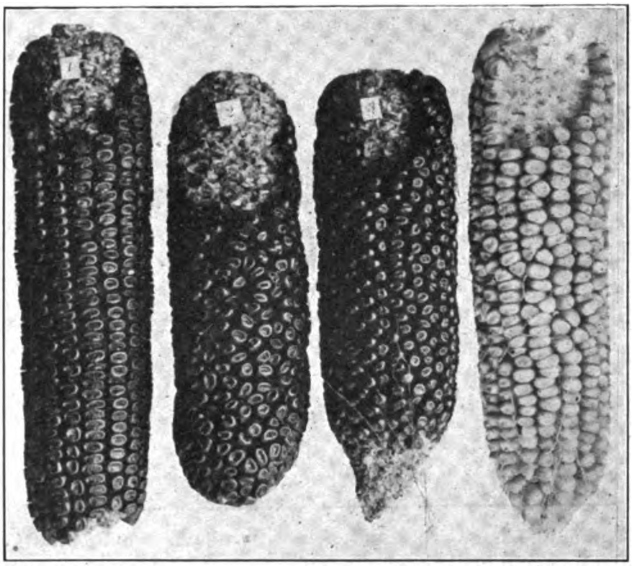

Fig. 1. Correlated cob, pericarp and silk colors. An F_1 ear with red cob, red pericarp, and dark silk and which is hybrid with respect to all these characters produces two types in F_2 in the ratio of three with red cob, red pericarp, and dark silks to one with white cob, colorless pericarp, and light silks. No other combination of colors is produced. (See Family 357, Table 1.)

color of cobs, pericarp, husks, silks, and anthers. This apparent correlation could not, in some of the cases at least, have been due to a single allelomorph. Pink color developed in the anthers where no color was seen in cob, pericarp, or husk (see Families 480, 489, 491, 495, 496). While in some families light silks were associated with colorless cob and pericarp and dark silks with colored cob and pericarp (Families 346, 357, 404, 480), in other families the plants with a colorless cob and pericarp had dark silks (489, 491, 492, 495, 496). Again while in most families a colored pericarp was associated with a colored cob and a colorless pericarp with a colorless cob, in other families color developed in the pericarp without any color showing in the cob (152, 335, 338, 354, 358) or the reverse (480). If, however, the colors of the cob, pericarp, etc., depend upon distinct

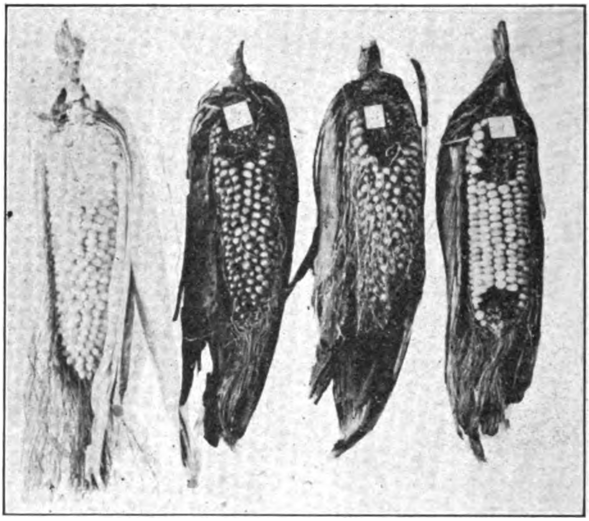

Fig. 2. Correlated husk, cob, and pericarp colors. An F_1 plant with hybrid dark purple husks and cob and purplish pericarp yields two types in F_2, in the ratio of three with the colors of F_1 to one without such colors. (See Family 489, Table 1.)

genes, these genes are certainly not independently inherited. With independent inheritance, if one parent had red cob, red pericarp, red husks and dark (red?) silks and the other parent had white cob, pericarp, and husks and light (white?) silks, we should expect the combination of the four recessives to occur only once in 256 F_2 individuals. In Family 346 this combination occurs 28 times in 118 cases and the combination of the four dominants occurs in all the other 90 plants. In case of all the 951 F_2 plants included in Table 1, 706 had all the dominant characters and 240 all the recessive characters in which the types differed, and only five had unexpected color characters (where theoretically there should have been 713 dominant to 238 recessives). In four of the five "off-type" plants the color combinations were those of other families growing in the same field with the F_1 plants concerned, which makes it very probable that the four were the result of accidental crossing in F_1—a possibility that anyone will admit who has ever worked with colors showing xenia. The fifth case is explainable only on the assumption of a "break" in the correlation or of a mistake in making the records.

Table 2 presents records similar to those of Table 1 except that the individuals called F_1 in Table 2 were crossed in various ways instead of being self-pollinated as was the case with the plants recorded in Table 1. Of these crossed plants, at least one individual of the two concerned in each separate cross was heterozygous and in some cases both were so. Some of the "F_1's" were evidently real F_1 hybrids of the pistillate parent shown in the table with an unknown staminate parent, and in other cases the pistillate parent was itself heterozygous. A few entries in Table 2 are repeated from Table 1 for comparison with related families.

TABLE 2.—*Correlated colors in maize.*

Pistil'ate parent				F_1 from open-pollinated P_1							F_2 from selfed or crossed F_1						
Plant No.	Color of			Plant No.	Color of					Poll-ination	Family No.	Frequency	Color of				
	Cobs	Pericarp	Husks		Cobs	Pericarp	Husks	Silks	Anthers				Cobs	Pericarp	Husks	Silks	Anthers
271	DP	P	DP	$271_{(12)}$	DP	P	DP	..	...	}×[8]	484	14	DP	P	DP	D	DP
80	DP	P	DP	$80_{(8)}$	W	W	W	..	....			13	P	PW	P	D	DP
148	....	W	....	$148_{(1)}$	R	W	W	D	....	(×)[9]	480	12	R	W	W	D	Pk
												5	W	W	W	L	Pk
271	DP	P	DP	$271_{(6)}$	DP	P	DP	D	DP	(×)	489	11	DP	P	DP	D	DP
												4	W	W	W	D	Pk
											479	9	DP	P	DP	D	DP
148	....	W	...	$148_{(1)}$	R	W	W	D	....	}×		6	RP	P	(D)P	D	DP[9]
271	DP	P	DP	$271_{(5)}$	DP	P	DP	D	DP			3	R	W	W	D	Pk
												5	W	W	W	D	Pk
$41_{(2)}$	W	W	...	$173_{(12)}$	W	W	...	..	...	}×	476	10	W	LB	.....	..	....
26	W	LB	...	$26_{(8)}$	W	LB	....	..	....								
$25A_{(1)}$	W	W	...	$179_{(2)}$	W	W	....	.	...	}×	473	24	W	LB	.....	..	....
26	W	LB	...	$26_{(3)}$	W	LB	..	..	.								
$40_{(1)}$	W	W	...	$169_{(16)}$	W	W	...	..	...	}×	452	12	V	V	....	D	....
166	....	V	.	$166_{(3)}$	V	V	..	..	.			(3	R	R	.....	D	..)[10]
												11	W	W	....	L	....
26	W	LB	....	$26_{(8)}$	W	LB	....	..	....	}×	440	22	V	V	.....	..	....
166	....	V	...	$166_{(4)}$	V	V	....	..	...			(3	R	R	.....	..	..)[10]
												15	W	LB	......	..	....
22	W	HR	...	$22_{(26)}$	W	HR	....	..	....	}×	429	42	W	HR	....	..	....
26	W	LB	...	$26_{(5)}$	W	LB	..	..	...			32	W	LB	. ...	..	...
22	W	HR	...	$22_{(28)}$	W	HR	..	..	...	(×)	324	29	W	HR	. . .	..	....
												10	W	W	......	..	....
19	R	V	..	$19E_{(11)}$	V	V	..	..	.	}×	421	33	V	V	.....	..	.....
22	W	HR	...	$22_{(28)}$	W	HR	..	..	....								
22	W	HR	...	$22_{(26)}$	W	HR	...	..	....	}×	430	11	V	V	......	..	....
19	R	V	...	$19E_{(14)}$	V	V	...	.	..			(1	R	R	......	..	..)[10]
												5	W	HR	......	..	....
												5	W	W	......	..	...
$40_{(1)}$	W	W	...	$169_{(6)}$	W	W	...	..	....	}×	469	13	V	V	.....	D	....
19	R	V	....	$19E_{(14)}$	V	V	....	..	....			(2	R	R	....	D	..)[10]
												20	W	W	......	L	....
21	R	R	...	$21_{(14)}$	R	R	....	.	....	}×	424	35	R	R	.....	..	....[11]
$40_{(1)}$	R	V	....	$19E_{(19)}$	V	V	...	..	...			37	V	V	......	..	....
												(2	W	W	......	..	..)[10]
$25A_{(1)}$	W	W	....	$179_{(4)}$	W	W	....	..	....	}×	465	10	R	R	......	..	....[11]
21	R	R	....	$21_{(13)}$	R	R	....	..	...			9	V	V	......	..	....
$40_{(1)}$	W	W	....	$169_{(6)}$	W	W	. ..	..	....	}×	464	33	R	R	.....	..	....[11]
21	R	R	...	$21_{(14)}$	R	R	....	..	...			24	V	V	......	..	....
												(1	W	W	. ....	..	..)[10]
21	R	R	....	$21_{(14)}$	R	R	...	.	....	}×	425	25	R	R	.....	..	....[11]
22	W	HR	.	$22_{(26)}$	W	HR		..	. .	..		10	V	V	......	..	...

These records show the same correlations exhibited by the records in Table 1. Of the 433 individuals (not including the ones repeated from Table 1) there is no case in which the correlation fails. (See figure 3.) Where two types are expected to occur in equal numbers in F_2 the observed numbers depart considerably from the expectation as shown by the following summary:

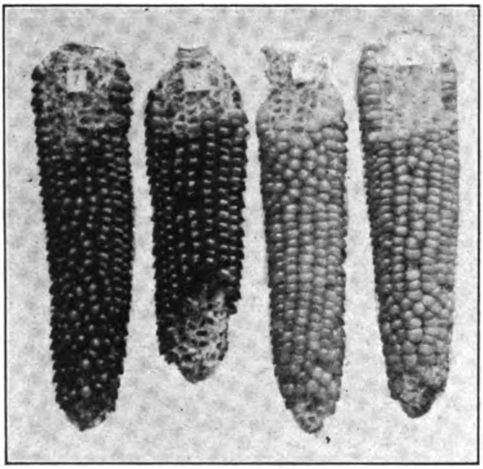

Fig. 3. Correlated cob and pericarp colors. An F_1 plant hybrid with respect to variegated-red cob and pericarp when crossed with a race that lacks red in these parts produces in F_2 only two types in equal numbers, one type with cob and pericarp colors like F_1, and the other without red in cob or pericarp. (See Family 440, Table 2.)

	Observed	Expected
Dominant or epistatic correlated colors	214	194
Recessive or hypostatic correlated colors	174	194
Total	388	388
Ratio	1.23:1	1:1

The greater number of individuals in the first of the two classes is probably to be explained in part (certainly not wholly) by the frequent production of red offspring by variegated individuals. Sometimes these red ears are mere bud variations, for occasionally, tho rarely, a solid-red (or nearly solid-red) ear is found on a plant with normally variegated ears, just as single ears with normally variegated grains in the main are occasionally found to have large patches of solid-red grains. (See figures 4 and 5.) It is possible that there occurs in corn with variegated ears something similar to what Correns has recently shown to occur in case of variegated flowers and leaves of *Mirabilis.*[12] All that I am ready to say at present is that the red

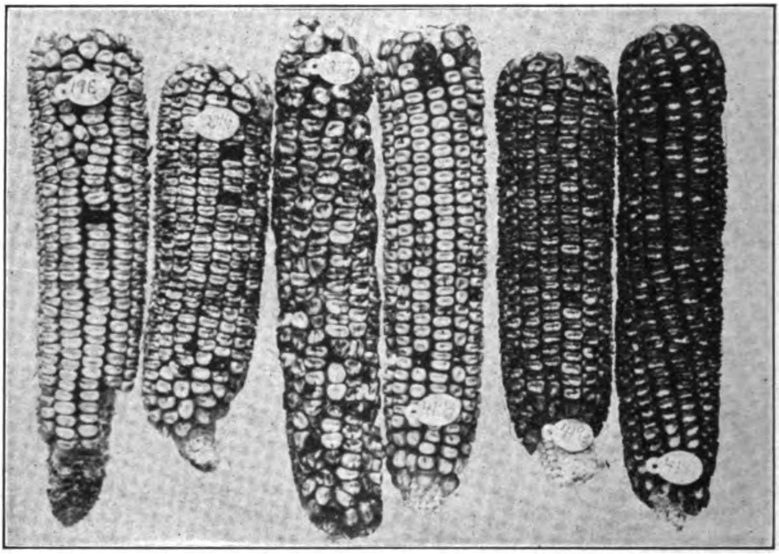

Fig. 4. Common forms of variegation of pericarp color. Some ears have evenly fine striped grains thruout, giving them an almost solid red appearance. At the other extreme are ears with no pericarp color except for an occasional striped or nearly solid red grain. Solid red, entirely colorless, and variously striped grains not uncommonly occur on the same ear.

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ears produced in almost any lot of variegated corn do not appear to behave in the simple way that the green type originating from variegated four-o'clock does according to Correns.

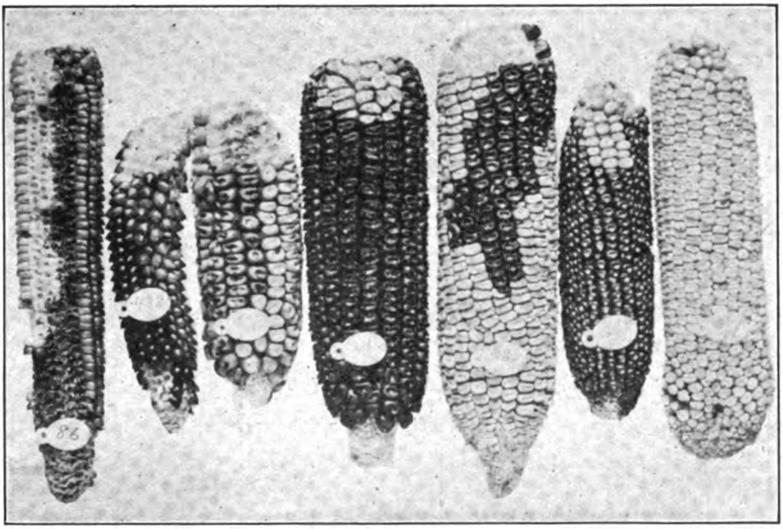

Fig. 5. Rare forms of variegated ears. Large or small patches of grains have much darker or much lighter variegated pericarp than the other grains of the ear. In some cases the light patches are made up of apparently colorless grains and in some cases the dark patches consist of solid red grains only. Not infrequently the cob beneath the dark patch is solid red while that beneath the light patch shows a light variegation; the exact correspondence in position of the dark and light patches of the cob with those of the grains is often most striking. It sometimes happens, however, that pronounced dark or light groups of grains occur without any corresponding dark or light areas on the cob, and similarly there are often dark and light spots on the cob without anything corresponding to them in the coloration of the grains.

ciated in certain gametes and all lacking from other gametes. If there really are distinct genes for color in cobs, pericarp, husks, silk, anthers, etc., it can certainly be said that, in the cases presented, these genes were in some way strongly bound together. That is, there was (with one possible exception—Family 496, Table 1) perfect genetic correlation. I have now to present a few cases in which a dominant color of the cob is alleolomorphic to a dominant color of the pericarp. Table 3 includes all these cases.

TABLE 3.—*Allelomorphic colors in maize.*

	Pistillate parent:			F$_1$ from open-pollinated P:				F$_2$ from selfed or crossed F$_1$				
		Color of			Color of					Color of		
Group No.	Plant No.	Cobs	Pericarp	Plant No.	Cobs	Pericarp	Pollination	Family No.	Frequency	Cobs	Pericarp	Silks
1	22$_{(5)}$	W	HR	97$_{(1)}$	R	HR	(×)	332	14	R	HR	D
									6	R	W	D
									5	W	HR	L
	19	R	V	19A$_{(1)}$	R	V	(×)	290	25	R	V	
									(3	R	R	...)[13]
									18	R	W	......
									15	V	V	......
	19	R	V	19E$_{(16)}$	R	V	×	416	16	R	W	......
	26A$_{(1)}$	W	W	179$_{(4)}$	W	W			18	V	V	......
2	47	W	W	47$_{(22)}$	W	W	×	457	10	V	V	......
	21	R	R	21$_{(16)}$	V	V			9	W	W	......
	21	R	R	21$_{(14)}$	V	V	×	426	14	V	V	......
	22	W	HR	22$_{(27)}$	W	HR			15	W	HR	......
	22	W	HR	22$_{(20)}$	W	HR	×	431	20	R	HR	......
	19	R	V	19E$_{(18)}$	R	V			18	V	V	......
									(3	R	R	...)[13]
									(2	W	HR	...)[14]
	38$_{(7)}$	W	W	172$_{(2)}$	W	W	×	470	24	R	W	......
	19	R	V	19E$_{(12)}$	R	V			19	V	V	......
									(1	R	R	...)[13]

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[13] These reds are probably extreme forms of the variegation.

[14] One of these two white-cobbed plants had broad, smooth, shallow grains many of which had black aleurone, indicating quite certainly an accidental cross with some plant of black flour corn. That the other white-cobbed plant was also the result of accidental pollination seems probable, for it had fairly smooth dent grains similar to the pistillate parent 22$_{(20)}$, while all of the other 41 red-cobbed and variegated-cobbed individuals of this lot had rather rough dent grains somewhat like the staminate-parent 19E$_{(12)}$.

Both the F_1 plants $97_{(1)}$ and $19A_{(1)}$ (Table 3) exhibited dominant cob and pericarp colors and were evidently heterozygous for both these characters, as indicated by their F_2 families (332 and 290 respectively). With these two characters inherited independently there should have occurred four F_2 classes giving the usual dihybrid ratio of 9:3:3:1, while if the colors were perfectly correlated the F_2 progenies should have shown two classes in the monohybrid ratio of 3:1. If, however, the two dominant characters exhibited spurious allelomorphism like that seen in sweet peas[15] the F_2 family should have consisted of three classes with the monohybrid ratio of 1:2:1. Combining these two families (332 and 290) and calling the dominant or epistatic cob color *A*, the dominant pericarp color *B*, and the absence of these colors *a* and *b* respectively, the formula of plants $97_{(1)}$ and $19A_{(1)}$ is *AB*. The classes and frequencies observed in F_2, together with the classes and frequencies expected according to the various modes of inheritance, are as follows:

Possible classes	Frequencies expected with—			Observed frequencies
	Perfect correlation	Independent inheritance	Spurious allelomorphism	
AB	65	49	43	41
Ab	0	16	22	24
aB	0	16	21	21
ab	21	5	0	0
Total	86	86	86	86

This showing is certainly very favorable to the assumption that cob and pericarp colors are here allelomorphic to each other. If this assumption is correct, F_1 plant $97_{(1)}$ must have produced gametes a part of which carried a gene for red cob but lacked the gene for colored pericarp and the rest of which carried a gene for half-red pericarp but no gene for cob color. (See figure 6.) Similarly F_1 plant $19A_{(1)}$, tho it had a red cob and variegated pericarp, could have produced no gametes with genes for that combination of colors. Some of the gametes must have had genes for variegated cob and variegated pericarp and the other gametes a gene for red cob but no gene for pericarp color.

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[15] Bateson, W. Mendel's Prin. Heredity, pp. 153-155 (1909).

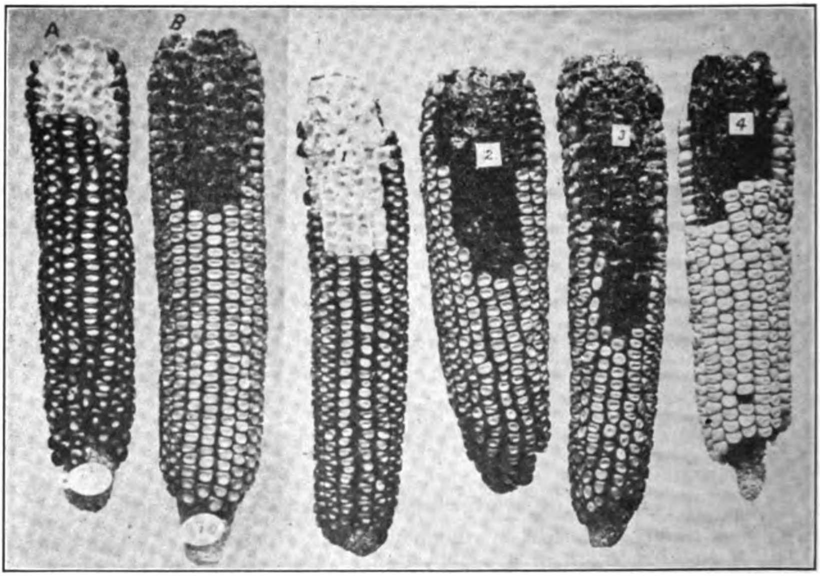

Fig. 6. Allelomorphic cob and pericarp colors. An F_1 ear hybrid with respect to its red cob and half-red pericarp (marked B in the cut) yielded in F_2 from self-pollination the three types seen in the four ears at the right (numbered 1 to 4), approximately in the ratio of one with white cob and half-red pericarp (No. 1), like the pistillate parent (A) of the F_1 plant, to two (Nos. 2 and 3) with red cob and half-red pericarp, like F_1, to one with red cob and a colorless pericarp (No. 4). No ears with white cob and colorless pericarp were produced. The staminate parent of this F_1 plant was unknown, but probably had red cob and colorless pericarp like ear No. 4. (See Family 332, Table 3.)

Another F_1 plant ($19E_{(16)}$) from the same pistillate parent (19) as the F_1 plant just considered ($19A_{(1)}$) and having the same color characters—red cob and variegated pericarp—was crossed with a plant ($179_{(4)}$) known to be homozygous for white cob and pericarp, thus affording an opportunity of determining whether plant 19E$_{(16)}$ produced any gametes with a combination of color genes like the combination of colors seen in the plant itself. F$_2$ family 416 was the result of this cross. The occurrence of 16 plants with red cobs and white pericarp, 18 plants with variegated cobs and pericarp, and no plants of any other type indicates clearly that only two classes of gametes (with respect to cob and pericarp colors) were produced by plant 19E$_{(16)}$. and these classes were exactly those assumed above for plant 19A$_{(1)}$ in accordance with the hypothesis of spurious allelomorphism of cob and pericarp colors. Group 2 of Table 3 gives

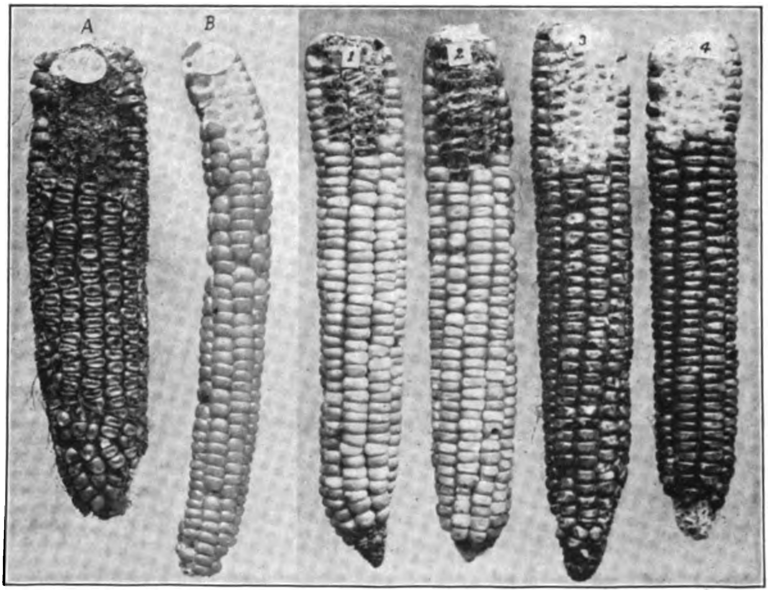

Fig. 7. Allelomorphic cob and pericarp colors. An F$_1$ plant (A) hybrid with respect to its red cob and variegated pericarp crossed with a

the results of two crosses of a third plant ($19E_{(12)}$) with red cob and variegated pericarp like plants $19A_{(1)}$ and $19E_{(16)}$ discussed above. That this third plant produced gametes just like those of the other two plants (with respect to cob and pericarp colors) is readily determined by an examination of the various plants and families in group 2 of Table 3.

Tho the evidence presented in Table 3 is by no means all that might be desired, it seems to me sufficient to establish the fact that spurious allelomorphism occurs with respect to cob and pericarp color in maize. The most convincing part of the evidence is not the F_2 ratios and not the absence of one of the four F_2 types expected from self-pollinated F_1 plants on the hypothesis of independent inheritance. It is the gametic analysis of the F_1 plants, made possible by crossing them with plants lacking genes for the characters concerned, that has furnished the most positive evidence. Families 416, 431 and 470 (Table 3) show plainly the classes of gametes that were produced by plants $19E_{(16)}$ and $19E_{(12)}$. (See figure 7.) If the epistatic cob and pericarp colors are *A* and *B* and the absence of these colors are *a* and *b* respectively, the F_1 plants $19E_{(16)}$ and $19E_{(12)}$ might be represented by the formula *AaBb*. The following statement compares the observed with the expected classes and frequencies of gametes of these F_1 plants:

Gametic classes	Expected frequencies with—			Observed frequencies
	Independent inheritance	Perfection correlation	Spurious allelomorphism	
AB....	30	60	0	0
Ab	30	0	60	60
aB	30	0	60	59
ab...	30	60	0	0
Total.........	120	120	120	119

It will be recalled that Webber reported a case of correlation between reddish silks. reddish stamens, reddish glumes, and colorless aleurone and between white or greenish silks, greenish stamens, greenish glumes, and black aleurone.[16] Or, as it might be expressed, colors of silks, stamens, and glumes were correlated with each other and allelomorphic to black aleurone. Webber reported that in some cases the correlation was broken. Reddish silks, for instance, were occasionally associated with greenish glumes and stamens and also greenish silks with reddish glumes and stamens. If purple (black) aleurone is allelomorphic to colored silks, anthers, etc., as Webber has shown and if silk and anther colors are correlated with certain cob and pericarp colors as my results indicate, purple aleurone ought to be allelomorphic to cob and pericarp colors. Whether this relation will be found to exist I cannot tell until another season. It is interesting to note, however, that a red aleurone color which is hypostatic to purple[17] is inherited independently of pericarp. cob and silk color. A plant with colorless cob and pericarp and red aleurone was crossed with a plant having red-variegated cob and pericarp and colorless aleurone and resulted in an F_1 with variegated-red cob and pericarp and heterozygous red aleurone, About 75 per cent. of the F_2 plants had variegated cobs and pericarps and dark silks (silk color was not noted in the earlier generations) and about 25 per cent. had white cobs, colorless pericarp, and light silks—perfect correlation as usual. If red aleurone had been correlated with colorless pericarp, white cob, and light silks (i. e. allelomorphic to pericarp, cob, and silk color), all F_2 plants that lacked color in cobs, pericarp, and silks should have been homozygous for red aleurone and all F_2 plants that had pericarp, cob, and silk color should either have lacked red aleurone altogether or have been heterozygous—never homozygous—for red aleurone. There were produced, however, F_2 plants without cob, pericarp, and silk color but with non-red aleurone, other F_2 plants without cob, pericarp, and silk color, but with heterozygous red aleurone, and finally F_2 plants with cob, pericarp, and silk color and with homozygous red aleurone, as well as the other combinations possible on the assumption of inheritance of red aleurone independently of cob, pericarp, and silk color. This does not argue against the allelomorphic inheritance of purple aleurone and dark silk color as shown by Webber, for if purple aleurone were allelomorphic to silk color, red aleurone could not be so unless it were correlated with purple aleurone. That red aleurone is independent of purple aleurone in inheritance was indicated in my paper before the American Breeders' Association, referred to above. Of 6,247 F_2 individuals of a cross of purple × non-colored aleurone, there were 3,606 purple, 1,095 red, and 1,549 non-colored—distinctly a dihybrid ratio approximating closely 9:3:4, thus indicating independent inheritance of the two aleurone colors.

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[16] Webber, H. J. Amer. Breed. Assoc. 2 : 76-79 (1906).

[17] In a paper read before the American Breeders' Association, December, 1909, to be published in Volume VI, I discussed the occurrence of red aleurone in F_2 of a cross of Black Mexican sweet corn (purple aleurone) with Queen's Golden pop corn (non-colored aleurone) and its behavior in inheritance.

GENETIC CORRELATION AND SPURIOUS ALLELOMORPHISM COMPARED

Granting that in maize there is perfect genetic correlation between certain characters under certain circumstances and that apparently the same characters are allelomorphic to each other under other circumstances, it becomes interesting to note what these circumstances are. Apparently the only difference in circumstances is that in the case of perfect correlation two dominant characters, say red cob and red pericarp, are both together in one parent and both absent from the other parent, while in case of spurious allelomorphism the two dominant characters happen to be in separate parents, one parent having say red cob and colorless pericarp and the other non-red cob and red pericarp. That is, if two dominant characters happen the beginning, they remain separate afterwards—spurious allelomorphism. In presenting the conceptions of gametic coupling and of spurious allelomorphism, Bateson has warned us against confusing the two ideas.[18] To me, however, they seem fundamentally the same phenomenon. Bateson (*loc. cit.*) pointed out that if a case of perfect coupling were known it might be regarded as the *converse* of spurious allelomorphism; that is, the former might be represented as the result of attraction and the latter as the result of repulsion between dominant factors. For me, however, it is difficult to conceive of two genes always attracting each other under certain circumstances and just as persistently repelling each other under other circumstances, particularly when the only discernible difference in the circumstances is that in one case both characters happened to be present in one parent and in the other case the two were in separate parents. Gametic coupling and spurious allelomorphism seem to me to bear the same relation to each other as do positive and negative correlation in fluctuations. The latter seem directly opposite; but nevertheless to say, for instance, that earliness in some plant is negatively correlated with tallness is merely another way of saying that it is positively correlated with shortness. Similarly, to say that red pericarp in maize is allelomorphic to red cob is to say also that it is genetically correlated with white cob. Spurious allelomorphism, in this case at least, is to be regarded as negative genetic correlation. In one case two dominant characters are associated; in the other case one dominant character is associated with the absence of the other one. These relationships may be represented graphically somewhat as I represented the possible relationships of the two fac-

Where A and B are from the same parent—

$AB . ab$, indicating independent inheritance.

$\overset{\frown}{AB} . \overset{\frown}{ab}$, indicating perfect correlation.

Where A and B are from different parents—

$Ab . aB$, indicating independent inheritance.

$\overset{\frown}{Ab} . \overset{\frown}{aB}$, indicating spurious allelomorphism.

RELATION OF THE FOREGOING TO THE CHROMOSOME THEORY OF INHERITANCE

If a positive character can be linked with the *absence* of some other character, as seems to be true in cases of spurious allelomorphism, what can be the mechanism of such coupling? Altho this is pure speculation, it is perhaps worth while to note that *if genes were definitely located in chromosomes and that if parental chromosomes separated bodily at the reduction division* (as has been suggested by several writers), *we should have an "explanation" not only of perfect genetic correlation and of allelomorphism—spurious or otherwise—but of independent inheritance as well.* If the genes for red cob and red pericarp in maize, for instance, were in *separate chromosomes* of a gamete the fact would insure *independent* inheritance with the production of four F_2 types in the ordinary dihybrid ratio of 9:3:3:1; if the two were in the *same chromosome* perfect *gametic coupling* must result and two F_2 types must appear in the monohybrid ratio of 3:1; and finally if the two genes were in separate but *homologous* chromosomes, spurious *allelomorphism* would surely appear with its three F_2 types and monohybrid ratio of 1:2:1.[20] Furthermore if there happened to be two genes for the same character located in separate chromosomes of a gamete, an F_2 ratio of 15:1 must result instead of the usual 3:1 ratio, or if there were three genes in separate chromosomes, a ratio of 63:1, and so on, thus affording a picture of the mechanism that may possibly have been responsible for the unusual ratios observed in color studies of wheat by Nilson-Ehle and of corn by East[21] as well as of that responsible for the many F_2 types seen where parents differ greatly in size.[22] Contrary to Morgan's statement, the production of pure gametes by a hybrid does *not* require "that each particular character, or whatever it is that produces the character, be confined to a single chromosome."[23] If a par-

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[20] Note added February, 1911. After this statement had been written, Morgan reported (Amer. Nat. 45 : 74-78) results of the greatest importance in regard to sex-limited inheritance in *Drosophila* which, as he has shown, can be explained apparently only on the two following suppositions namely, *first*, that the genes for long wings and for red eyes when present are located in the same chromosome that bears the gene (or genes?) for femaleness; and *second*, that homologous genes may exchange places during the intimate association of homologous chromosomes just prior to the reduction division. It is obvious that in ordinary cases, if genes can thus shift from one to the other of homologous chromosomes,

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independent inheritance of the characters concerned would be assured just as certainly by this means as by their location in separate non-homologous chromosomes. That the inheritance of red and white eyes and of long and short wings in Morgan's flies was not entirely independent of sex is doubtless due, as Morgan has pointed out, to the circumstance that the male insect lacks one sex chromosome so that there can be no shifting of genes between homologous chromosomes preceding the formation of the sperm cells. That wing length and eye color are inherited independently of each other in certain cases, tho both are sex-limited, is due to the circumstance that in the female, where both of the homologous sex chromosomes are present, the gene for femaleness is carried in each of these chromosomes (homozygosis of sex here being essential to femaleness), thus insuring its presence in every egg cell even tho it may shift between homologous chromosomes in the same way that the genes for wing length and eye color are supposed to do. In short, eye color and wing length are independent of each other in the formation of the eggs but coupled or allelomorphic in the formation of the sperms.

Evidently the genes for the cob and pericarp colors of corn reported here do not shift from one chromosome to its homolog, else independent, rather than correlated or allelomorphic, inheritance would result, for in corn, unlike *Drosophila* and many other insects, the male and female gametes of any one individual are alike in so far as the matter has been experimentally tested. If certain genes shift so readily that it is a mere matter of chance whether they are finally located in one or other of homologous chromosomes while other genes do not shift at all, the possibility of an occasional shifting of ordinarily non-shifting genes and of occasional failure to shift on the part of normally shifting genes is not to be overlooked in attempting to explain unexpected ratios between supposedly independent characters as well as in attempts to account for "breaks" in correlation, partial gametic coupling, and similar phenomena.

[21] East, E. M. Amer. Nat. 44 : 72, 73 (1910).

[22] Lang, A. Zeitschrift für Inductive Abstammungs und Vererbungslehre. 4 : 1-23 (1910); Emerson, R. A. Amer. Nat. 44 : 739-746 (1910).

[23] Morgan, T. H. Amer. Nat. 44 : 466 (1910).

ticular character were represented by genes in two chromosomes. pure gametes might nevertheless be formed, some of them having the character represented in *one* chromosome, some in *two*, and same in *none*. If there can be two or three genes for a single character located in as many separate chromosomes, may there not be some characters represented by a gene in *every* chromosome? And if there were many characters of a fundamental nature represented in all chromosomes, why should we expect, as Morgan insists, "the isolated blastomeres of the dispermic eggs [of sea urchins] to produce different kinds of organs, heterogenously united"?[24] Or again, to take another example cited by Morgan, why need one phylloxeran differ from another in more than minor points even tho the one has 44 and the other only 12 chromosomes, provided the genes for many fundamental characters might be located in all the chromosomes of both species?[25]

POSSIBLE GENETIC CORRELATION OF SIZES AND OTHER CHARACTERS

In a recent paper on the inheritance of sizes and shapes in plants[26] I called attention to the possibility of there being definite correlations between different dimensions, as length and breadth, of the same organ. If length and breadth were inherited independently, a large round bean crossed with a small round one should yield in F_2 some long slender beans and some very short, broad ones, but in fact only round beans—large, medium, and small—are produced. Again, if a very long slender bean is crossed with a large round one there should occur in F_2, on the beans. It is true that in certain gourd crosses[27] individuals have occurred in F_2 with fruits much longer than those of either parent or of F_1, but this may have been due to the chance meeting in F_2 of homozygous length characters that were separate in the parents and heterozygous in F_1.

I have now to note a very interesting case of correlation in maize between dwarfness and broad leaves, the presence of stamens thruout the ear (usually three well-developed and three abortive ones to each grain), club-shaped tassels, and defective anthers—or shall I say a case of spurious allelomorphism of tallness and these other characters? This correlation was observed in three families of my corn in 1910. Two of these families came from one mother plant two generations earlier, and the third family was unrelated to the other two so far as known. The three parent plants grown in 1909, from which the three families arose, were normal in height, breadth of leaves, monœcism, etc., and were carefully self-pollinated. Each of the three 1910 families was made up of normal tall, monœcious plants and dwarf, andromonœcious ones. The andromonœcious plants were readily distinguished from the others at sight in all three families by their short broad leaves and their stout few-branched tassels, and in two of the families by their extreme dwarfness. While the andromonœcious plants of the third family averaged much shorter than the normal plants, the two types overlapped so that many individuals could not have been classified by height alone. Dwarfness in all cases was due to shortened internodes, the number of nodes always being about the same as in the tall plants. Altho the andromonœcious plants produced considerable pollen, the anthers of the tassels did not shed the pollen normally. Almost no pollen could be collected in the ordinary way in paper bags enclosing the tassels. In fact it was necessary to scrape the pollen from the anthers individually in order to get enough to self-pollinate a few ears. The pollen produced by the anthers on the ears was not examined.[28] Of the "normal" plants of these same families, all produced pollen abundantly so far as observed, all had slender many-branched tassels, and all had ears of the usual kind with apparently no trace of stamens.

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[27] These crosses were made by F. W. HofMann.

In the three families together there were 107 of the tall monœcious plants and 25 of the dwarf andromonœcious ones at the time the plants had finished their growth. Whether any of the very dwarf plants had been crowded out while young is not known. The important consideration here is not the ratio of the two types but rather the fact that so many very diverse characters were so definitely correlated. While I can at present offer little or no evidence that all these correlated characters are not due to a single gene, it nevertheless seems unreasonable that such unlike characters as internode length, branching of tassels, the presence of stamens thruout the ears, etc., should be determined by a single gene, while such similar characters as red color in the pericarp and red color in the cob are due to distinct genes. Apparently the case under consideration is one of perfect correlation of distinct characters.

Not the least interesting feature of the maize families discussed above is the fact that in two of them the two height classes were so sharply segregated. The three parent plants grown in 1909 were evidently heterozygous in height as well as in characters correlated with height. In accordance with the behavior of other corn hybrids the parents of which differed much in size, there were to have been expected in F_2 all grades from the tallest to the shortest plants distributed in such a way as to form a normal frequency curve. (See figure 8.) No such gradation of heights occurred, however, in two of these families. (See figure 9.) A comparison of the height classes of the three families with the height classes of the parents and of F_2 of a cross of a tall dent corn (Missouri) with a dwarf pop corn (Tom Thumb) is afforded in the following table:

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[28] Plants similar in many respects to the dwarf andromonœcious ones noted here have been studied previously by E. G. Montgomery and E. M. East. Montgomery's paper entitled "Perfect Flowers, in Maize" is to appear shortly in Popular Science Monthly, and East's description is included in a publication to be issued by the New Haven Connecticut Agricultural Experiment Station. Blaringhem has also described and illustrated hermaphrodite ears of maize much like those that I have seen. (Blaringhem, L. Mutation et Traumatismes, Paris, 1908.)

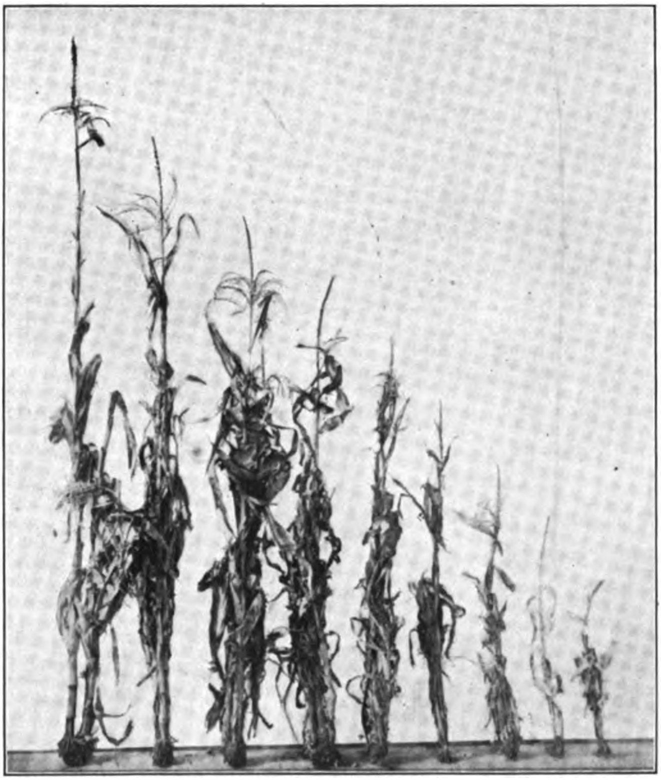

Fig. 8. Variation in height in F_2 of a cross of the tall Missouri dent and the dwarf Tom Thumb pop. All gradations in height occur from the tallest to the shortest. Plants of intermediate height are much more numerous than very tall and very dwarf ones. (See Table 4.)

TABLE 4.—*Variations in height in maize hybrids.*

Maize families	Frequency for height classes varying by 20 *cm.*											
	40	60	80	100	120	140	160	180	200	220	240	260
Dwarf-tall hybrid—												
Parents	...	...	10	11	...	...	1	3	5	7	5	1
, Fhybrid.	...	...	2	3	22	50	61	55	23	5	1	...
Correlation family No. 1	2	...	...	...	1	6	6	8	...	...	...	...
Correlation family No. 2	...	...	1	5	2	...	5	10	13	4	...	...
Correlation family No. 3—												
Andromonœcious plants	...	...	1	1	2	7	2	2	...	...	...	...
Monœcious plants	...	...	...	...	1	2	10	14	17	9	...	...
All plants family No. 3	...	...	1	1	3	9	12	16	17	9	...	...

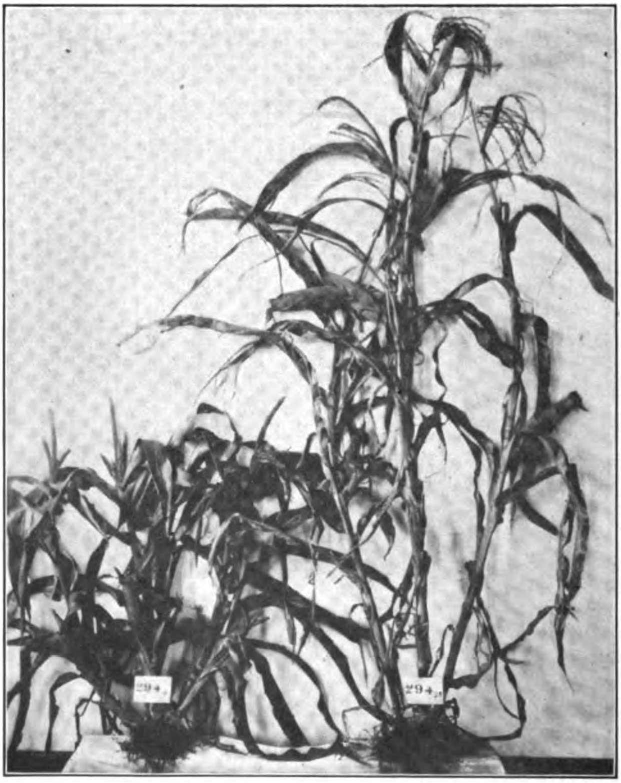

Fig. 9. Typical tall and dwarf plants in "correlation," Family No. 2. The two types do not intergrade completely in height. (See Table 4.)

If the gradation of heights in F_2 of the cross of tall dent with dwarf pop is to be explained as other cases of the sort are, we must assume that the parents differed by two or more, perhaps by several, height characters inherited independently of each other. But if Tom Thumb pop and Missouri dent differed by *several* height characters, is it probable that a similar difference in height between the original parents of the first two "correlation" families was due to only one character? While that assumption is perhaps not entirely unwarranted, it would seem more reasonable to suppose that similar differences in height are due to a similar number of height characters. If the latter assumption is correct, there must have been in the first two correlation families a *coupling of the several height characters* as well as of height with such characters as monœcism, branching of tassels, etc.

This calls up the question of height difference between other tall and dwarf plants, beans and peas for instance, with their simple three-to-one segregation in F_2. Castle has called attention to the fact that the inheritance of dwarfness is different from that of ordinary variations in height, the former being discontinuous and the latter, in his opinion, blending.[29] Since we are now, however, coming to regard "blending" as the *independent* inheritance of the *several* incompletely dominant characters by which the parents are assumed to differ, we must explain in terms of *discontinuity* the difference between the inheritance of dwarfness in such plants as peas and beans and that of dwarfness in such maize varieties as Tom Thumb. It is perhaps possible that a tall pea differs from a dwarf one by a single height character while a tall maize differs from Tom Thumb by several height characters, but it must not be forgotten in this connection that some tall peas are much taller than other tall peas and some dwarf ones more dwarf than other dwarf ones. If a very tall pea differs from a tall one by one size character, is it not probable that the very tall pea differs from the very dwarf one by several size characters? Then if a cross of a very tall pea with a very dwarf one exhibits simple three-to-one segregation in F_2, is it unreasonable to assume that the several size characters by which the two parents differ are genetically correlated and that to this circumstance is due the simple segregation?[30]

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[29] Carnegie Inst. Pub. No. 114, pp. 43, 44 (1909).

To accord with this view we must assume that a tall plant arises from a taller one by the loss of a single height gene and a dwarf plant by the loss of several genes, or that the process is reversed. On the view that in the case of such plants as peas very tall and very dwarf types differ by a single height gene we must assume that the various height types have arisen thru the *modification* of an original height character. While one must keep both views in mind, my experience with cob and pericarp colors, as well as with the inheritance of sizes in several plants, rather inclines me at present toward the former of these views. Given a type of corn with distinct cob-color and pericarp-color characters each represented by a gene in the same chromosome (to revert to the chromosome hypothesis of inheritance), it is conceivable that perfect genetic correlation might become manifest by the loss of both genes from the same chromosome (not necessarily at the same time) and that spurious allelomorphism might result from the loss of the gene for one character from one chromosome and the loss (at some other time perhaps) of the gene for the other character from the homologous chromosome. If this has taken place with color characters it is just as likely to have taken place also with size characters. That the different size characters for certain plants or plant parts should all be represented in one chromosome, thereby being correlated, while those for other plants or other parts of the same plant are represented in different chromosomes, thus independently inherited, is perhaps a no less reasonable idea than that purple aleurone should be represented in the same chromosome with cob, pericarp, and silk colors but in a separate chomosome from red aleurone. It must be admitted of course as conceivable that even red husks, red cob, red pericarp, red silks, red anthers, etc., are one Mendelian character which has been variously *modified* so that in one case red appears in only a part of the pericarp, in another case is wanting from the whole pericarp, in a third does not appear in the silks or anthers or husks or in any one or more of these parts. But after having been once permanently modified in any of these ways, the modified character is a Mendelian "unit" distinct from the original character and allelomorphic to it. While color varieties like those discussed in this paper and such variations in size as exhibit simple three-to-one segregation in F_2 may therefore have come about in either of these ways, i. e., by loss or gain of distinct characters or by modification of a single character, it is difficult to see how the several independently inherited size characters by which certain size varieties are now thought to differ could have been produced by the modification of a single original size character. The positive determination of whether size varieties actually do differ by more than one size character as present results indicate and a determination of the interrelations of these characters in inheritance as regards coupling. allelomorphism, or independence are among the most important present-day problems in the field of genetics.

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[30] Except for the "correlation" families of corn described above, the only "size" crosses among those I have studied that give a monohybrid ratio in F_2 are crosses of climbing beans with bush beans. The difference here is really not so much a matter of size as of habit of growth. Climbing beans are practically indeterminate in growth, the axillary flowers forming first at the lower nodes and progressively higher as the main axis elongates so that there are often flowers at the top and ripe pods at the bottom of the same stalk. Bush beans are determinate in growth, the first flower cluster to form usually being the one that terminates the main axis, and this stalk cannot be made to elongate further. There are tall and dwarf climbing beans and tall and dwarf bush beans. Crosses of tall and dwarf bush beans result in an intermediate height in F_1 and apparently in a wide range of heights in F_2.

THE RELATION OF CLIMATIC FACTORS TO THE WATER USED BY THE CORN PLANT

By T. A. Kiesselbach and E. G. Montgomery

INTRODUCTION

The experiments reported in this paper were undertaken to contribute to the answer of two questions, viz.:

(1) What is the relation of the water content of the soil to plant growth and transpiration?

(2) What is the relation between climatic factors and transpiration?

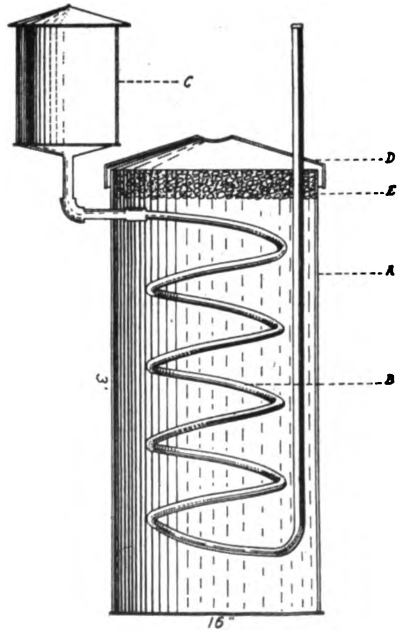

Fig. 1. Diagrammatic vertical section of potometer. *a.* Galvanized iron soil can, 3 feet by 16 inches. *b.* Perforated spiral coil for distributing water in soil. *c.* Six-quart can thru which all water is

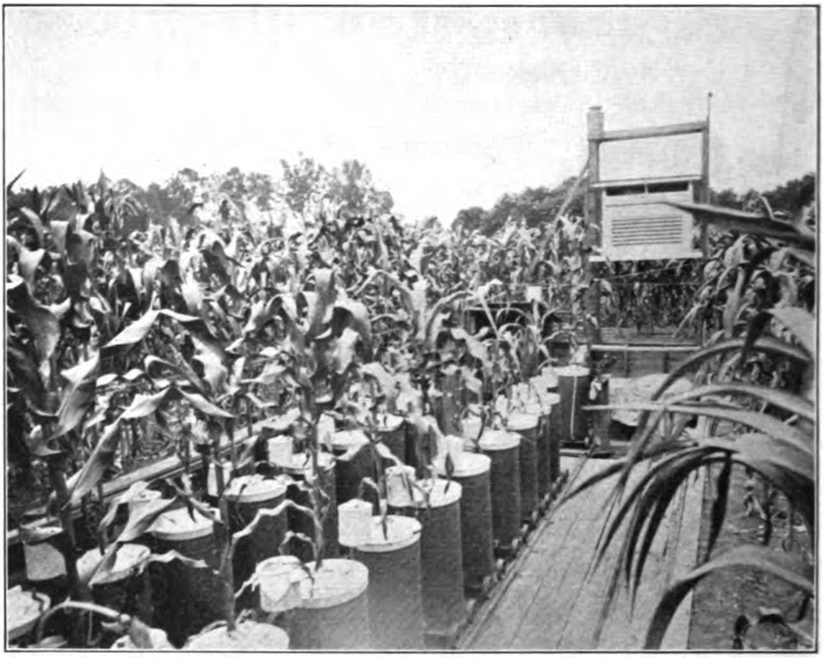

Fig. 2. Illustrating the manner of growing the plants from which these data were taken. Within the shelter at the far end were a self-recording thermometer, self-recording hygrometer, and apparatus for recording the wind movement. Above were a rain gage and an anemometer.

METHODS

Figures 1 and 2 illustrate the manner of growing the twenty corn plants from which these data were taken. In order to have the plants under field conditions they were grown in large galvanized iron potometers located in a cornfield and exposed to the general climatic conditions which prevailed in the field.

The potometers were three feet deep and sixteen inches in cornstalk. Buried in the soil and connected at the top with a covered 6-quart can, was a spiral coil made of three-eighths inch brass tubing 15 feet in length and perforated every eight inches. All water was added thru the small can and distributed uniformly thruout the soil by means of the perforated coil.

At any given time, the potometers, which stood on small individual trucks, were grouped on two double tracks on which they could be rolled back and forth. A set of platform scales graduated to one-fiftieth pound, ran on a separate track at right angles with these tracks in a shallow pit. The potometers were weighed individually each day at 7 p. m. by running them onto the scale platform.

The scale with the potometer was then rolled to a third empty track which received one-half of the potometers after they had been weighed. Then one of the first two tracks would be empty for receiving the rest. The whole process of weighing occupied one-half hour.

Five different degrees of soil saturation were maintained thruout the growing season. This made five sets of four plants each, varying from 35 to 100 per cent saturated soil. Saturation was regarded as the amount of water retained by the soil after drainage ceased from water poured on the soil surface. It required 100 pounds of water to saturate the 260 pounds moisture-free soil in each potometer. The five degrees saturation maintained were 100 per cent, 80 per cent, 60 per cent, 45 per cent, and 35 per cent, and may be expressed in several ways, as in the following table:

TABLE 1.—*Showing various ways of expressing the water content of the soil in the five degrees of saturation.*

No. of potometers averaged in each set	Water-free soil in each potometer	Water required to saturate soil	Saturation maintained	Per cent moisture on dry soil basis	Available water*	Per cent available water on dry-soil basis
	Pounds	*Pounds*	*Per cent*		*Pounds*	
4	260	100	100	38.46	68.8	26.46
4	260	100	80	30.77	48.8	18.77
4	260	100	60	23.08	28.8	11.08
4	260	100	45	17.31	13.8	5.31
4	260	100	35	13.46	3.8	1.46

* From considerable experience with this soil the non-available water was estimated at 12 per cent.

The daily transpiration was determined by loss in weight. The soil saturations were kept fairly constant by restoring, each evening, the exact quantity of water transpired during the day. When the loss was likely to be large, water was added twice each day.

In connection with these transpiration determinations accurate records were obtained in the immediate vicinity by means of standard self-recording instruments of those climatic factors which were likely to affect the rate of water loss.

The daily evaporation rate from a free-water surface was obtained by averaging the losses in weight from six 1-gallon glazed stone jars in which the water level was daily restored to one inch below the top of the jar. These jars were placed at different altitudes, ranging uniformly from the ground up to 10 feet above the ground. By taking the average evaporation from free-water surfaces distributed in this manner, data were obtained which may be compared with the transpiration from corn plants, the leaves of which vary in their height above ground.

In one experiment the evaporation rate was obtained by averaging the water loss from five Livingston porous clay cup evaporimeters.

Comparative data were also secured as to the wind velocity in a cornfield at altitudes of 4 feet and 10 feet above ground.

TABLE 2.—*Summary of growth relationship of corn plant in five different degrees of soil-moisture.*

No. of plants averaged (1)	Saturation maintained *Per cent* (2)	Per cent moisture on dry-soil basis (3)	Dry weight of stalk *Grams* (4)	Dry weight of ear *Grams* (5)	Ratio weight of ear to weight of stalk (6)	Dry weight of leaves *Grams* (7)	Total dry* weight of plant *Grams* (8)	Leaf area *Sq. in.* (9)
4	100	38.4	155.0	184.5	1.19	33.3	372.8	1109
4	80	30.7	205.7	236.6	1.14	41.8	484.1	1313
4	60	23.0	158.4	244.0	1.55	39.6	442.0	1206
4	45	17.3	97.0	159.2	1.62	40.9	297.1	1211
4	35	13.4	42.5	42.6	1.00	26.4	111.5	853

No. of plants averaged (1)	Saturation maintained *Per cent* (2)	Total water transpired *Pounds* (10)	Total water transpired *Kilos* (11)	Water used per gram dry weight of plant *Grams* (12)	Water used per sq. in. leaf area *Grams* (13)	Leaf area per gram dry weight *Sq. in.* (14)	Height of stalk *Inches* (15)	Date mature (16)
4	100	237.91	108.014	290	97.38	2.97	100	Sept. 20
4	80	279.90	127.077	262	96.78	2.71	101	Sept. 22
4	60	232.85	105.716	239	87.66	2.73	92	Sept. 24
4	45	150.14	68.163	229	56.28	4.07	75	Sept. 27
4	35	62.05	28.171	252	33.02	7.65	51	Oct. 2

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* The plants were thoroly dried at 110° C.

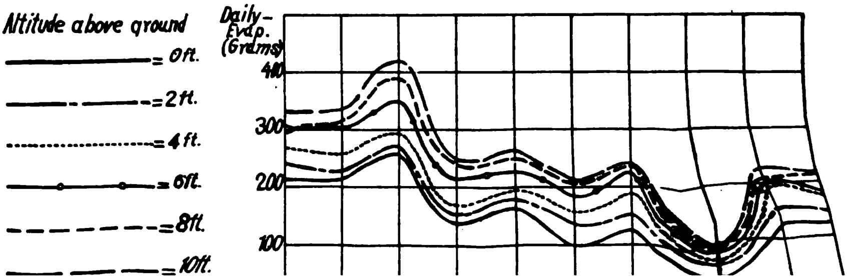
Table 2 gives a general summary of the yield, water requirements, and growth correlations. It is seen that the 20 plants fall naturally into three classes—one having more than the optimum (100 per cent), one with the optimum (60-80 per cent), and one with less than the optimum (35-45 per cent) water content. Again, they may be divided into two classes—one having an abundance of water and one where the water supply was deficient for normal development. It made little difference in the growth and transpiration relationships whether the soil was 60, 80, or 100 per cent saturated, except that 60 and 80 per cent proved to be more nearly optimum. When, however, the soil water content was reduced to 45 per cent and 35 per cent, the lack of water affected most of these relationships. It is to be questioned whether the results from these last two sets is very significant, for the growth was abnormal and the yield much reduced.

From a study of Table 3 and Chart I, which follow, it becomes evident that these small abnormal plants were not subjected in the same degree to the climatic factors conducive to heavy transpiration. A gradual increase is found in the evaporation rate from a free water surface at different altitudes between the ground and 10 feet above ground. The evaporation rate was only about one-half as great on the ground as 10 feet above ground. This is doubtless due to differences in temperature, shading, humidity, and wind velocity. During a six weeks' test (August 5 to September 23) of the comparative wind velocities at altitudes of 4 feet and 10 feet above ground in the cornfield, the total wind movement was found to be 6,528 miles at the higher elevation and only 1,755 miles at the lower, or 3.8 times

TABLE 3.—*Average daily evaporation for each week during two months from free-water surfaces of 36 square inch area at six different elevations in cornfield.*

Week ending	Evaporation from jar on ground	Evaporation from jar 2 ft. above ground	Evaporation from jar 4 ft. above ground	Evaporation from jar 6 ft. above ground	Evaporation from jar 8 ft. above ground	Evaporation from jar 10 ft. above ground
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
July 18,*7 p.m.						
18 "	213	240	267	305	298	334
25 "	213	230	259	303	315	338
Aug. 1 "	256	270	294	349	387	417
8 "	139	151	166	212	237	249
15 "	161	179	192	225	250	263
22 "	99	134	159	183	206	214
29 "	124	150	188	225	238	241
Sept. 5 "	39	61	70	85	95	98
12 "	122	152	194	206	210	230
19 "	121	141	171	178	215	220
Av. per day for season..	148.7	170.8	196.0	227.1	245.1	260.4

*Average of five days.



The greatest total weight was secured at 80 per cent saturation, the greatest total yield of ear at 60 per cent, and the highest proportion of ear at 45 per cent. This in general agrees with results obtained by European investigators, as summarized by Wollney, namely: that the greatest yield of grain is secured with a water content varying from 60 to 80 per cent saturation.

In regard to relative water used to produce an equal dry weight, this varied from 290, 262, and 239 for the three higher saturations. In the lower saturations the plants were abnormal in growth and so short that the data on these are not comparable, but in the first three cases the plants were all normal and of about the same height. At first it would appear from this that when the soil moisture is above normal the plant removes some of the excess by increased transpiration; but when it is noted that the total growth was reduced about one-fourth (column 8) the explanation rather seems to be that there was probably some physiological interference with growth.

The relative leaf area to dry weight produced is least under optimum conditions and greatest under the least favorable condition. It may seem inconsistent that plants in a dry location should have a high relative leaf area, but unfavorable conditions of any kind seem to reduce dry weight before leaf area, as is also shown in the case of excessive saturation (100 per cent). The low relative water loss per square inch leaf surface in the dry soils is due in part to the fact that these plants remained in a somewhat dormant stage until about the last of August, then rapidly developed leaves, reaching maximum leaf area about the first and second weeks of September, after the very hot weather, while the plants under normal conditions reached maximum leaf about the last of July.

The remainder of this paper is devoted to a study of transpiration and free-water-surface evaporation in relation to one another and to the climatic factors which affect them.

During 9 days in August, hourly transpiration and evaporation records were obtained during the day respectively from one corn plant and five Livingston porous clay cup evaporimeters. The average hourly data for the day and night, as well as the mean hourly weather factors, are shown in Table 4 and Chart II. (Only the total water loss was obtained for the night —7 p. m. to 7 a. m.—but in the chart the total amount has been arbitrarily distributed thruout the 12 hours in order to give an approximate graphic comparison with the day loss.)

TABLE 4.—*Summary of the transpiration, free-water-surface evaporation, and weather factors during successive hours of the day and night. (Only the total water losses were obtained for the night.)*

Hour ending	Water transpired from 1 plant	Av. water evaporated from 5 clay cup evaporimeters	Mean temperature	Mean relative humidity	Wind velocity
NIGHT	*Grams*	*Grams*	*Degrees F.*	*Per cent*	*Miles*
8 p. m.			75.3	55.8	1.61
9 "			71.9	64.2	1.56
10 "			67.8	71.1	2.00
11 "			66.9	75.1	2.17
12 "			63.9	80.2	3.11
1 a. m.			62.0	82.0	2.22
2 "			61.2	83.0	1.47
3 "			60.1	84.1	1.67
4 "			59.2	84.6	1.22
5 "			58.6	85.7	1.22
6 "			58.2	85.9	1.39
7 "			60.1	86.0	2.00
Av. for night	17	0.44	63.8	78.1	1.80
DAY					
8 a. m.	78	1.82	63.9	78.8	3.85
9 "	121	2.40	69.1	68.7	5.24
10 "	186	4.02	74.4	58.3	5.76
11 "	246	4.59	78.3	50.3	6.14
12 "	261	5.60	81.2	45.9	6.54
1 p. m.	305	5.71	83.0	42.3	7.66
2 "	349	6.37	84.1	40.3	7.56
3 "	327	5.59	84.6	39.0	7.68
4 "	271	5.83	84.6	38.9	7.60
5 "	227	4.39	83.9	39.4	6.99
6 "	203	3.88	82.9	40.8	6.00
7 "	108	3.46	80.6	44.6	3.72
Av. for day	223.5	4.47	79.2	48.9	6.23

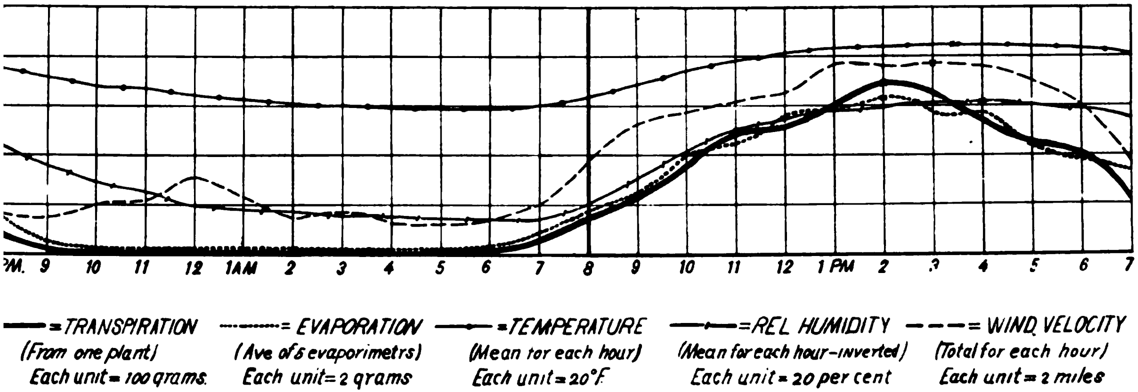


Chart II. Table 4 plotted. Summary of the transpiration, free-water-surface evaporation, and weather factors, during successive hours of the day and night.

It is interesting to note that the maximum transpiration and evaporation both occur at the same hour—2 p. m.—as the result of corresponding changes in the weather factors. Both rise and fall at nearly the same relative rate and have practically the same proportion to one another in the cool of the night as in the heat of the day. There is no tendency for transpiration to lag behind evaporation at 2 p. m., or to be greater morning and evening. In fact just the reverse is true, indicating that there is no effort on the part of the plant to either conserve or accelerate water loss when an abundance of water is present.

Table 5 and Charts III and IV contain a record of the average daily transpiration from 12 plants (60, 80, and 100 per cent saturations) and the average evaporation from the six free-water surfaces at different altitudes, as well as the mean temperature, relative humidity, and average hourly wind velocity 10 feet above ground, for the month beginning July 20 and ending August 20. The quantities of water transpired and evaporated are the total losses for 24 hours of each day (7 p. m. to 7 p. m.), while the weather factors listed are the mean for 12 daylight hours only (7 a. m. to 7 p. m.). Most of the water loss occurs during these 12 hours, and therefore the 12 hour mean for the weather factors is regarded as more important than the 24 hour mean. The 12 plants were practically constant in leaf-area and vigor thruout the 30 days.

TABLE 5.—*Showing the relationship between the daily transpiration, evaporation, and climatic factors.*

24 hours ending 7 p. m.	Water transpired per plant. (Av. 12 plants)	Water evap. from free water surface. (Av. 6 jars)	Mean hourly temperature. (7 a. m.-7 p. m.)	Mean relative humidity. (7 a. m.-7 p. m.)	Average hourly wind velocity 10 ft. above ground	Per cent of possible sunshine
	Grams	*Grams*	*Degrees F.*	*Per cent*	*Miles*	
July 20	951	200	79.2	52 4	4.7	46
" 21	2522	327	88.0	44.1	8.0	90
" 22	2350	278	84.4	53.6	6.7	75
" 23	1933	215	80.3	56 5	5.8	89
" 24	3211	311	90.9	24.7	4.4	100
" 25	3307	379	92.6	44.6	8.3	73
" 26	2955	382	89.9	53.7	8.2	98
" 27	4550	454	97.2	26 7	9.0	95
" 28	2333	372	84.4	58.8	11.1	62
" 29	1579	173	81.7	54.5	4.7	34
" 30	2802	232	83.8	34.2	4.5	98
" 31	3561	314	85.7	38.2	6.0	99
Aug. 1	3982	374	90.3	46.4	6.8	91
" 2	3419	311	88.2	53.1	4.6	85
" 3	2143	204	82.6	45.7	6.7	88
" 4	2479	236	77.2	45.7	5.6	84
" 5	1867	163	76.7	43.3	4.7	48
" 6	1582	147	74.2	43.0	4.4	30
" 7	2533	193	79.0	42.1	3.7	84
" 8	857	91	71.1	73.2	5.5	24
" 9	2438	319	76.1	40.6	9.0	100
" 10	2815	256	80.4	41.3	6.5	89
" 11	2571	259	81.5	57.2	6.9	93
" 12	2518	241	83.0	58.6	8.1	65
" 13	708	105	75 1	77.3	5.7	13
" 14	1098	139	78.6	68.3	6.0	45
" 15	2094	163	82.4	61.3	4.8	65
" 16	2850	219	88.3	56.2	4.7	72
" 18-19	1104	108	75.2	68.7	5.0	61
" 20	2165	198	82.0	63.1	3.7	99

The fluctuation in water loss by transpiration and evaporation is very marked from day to day. In general, both respond to changes in the weather conditions in much the same degree. In nearly all cases these changes in water loss can be accounted for by corresponding changes in one or more of the climatic factors. Of these, relative humidity and temperature appear to be most effective.

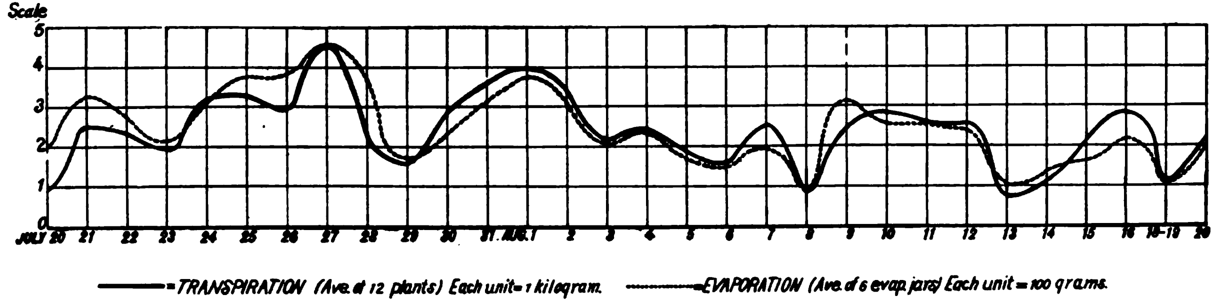


Chart III. The daily transpiration and evaporation data of Table 5, plotted to show the close relationship between transpiration by plants and the evaporation from a free-water surface.

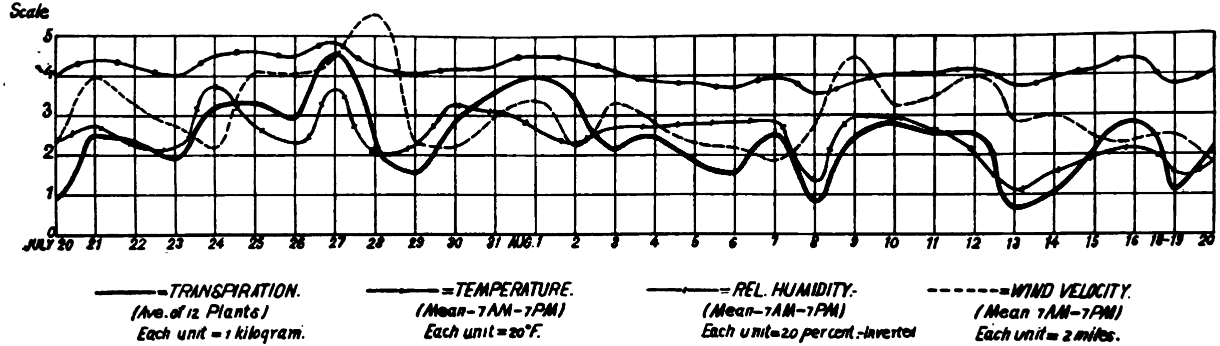


Chart IV. The transpiration and weather data of Table 5, plotted to show the daily relationship between the two.

On July 27 at 2 p. m. the temperature was the highest and the relative humidity the lowest for any single hour during the season, and the wind velocity was greater on only one other day, while the sun shone 95 per cent of the day. Here we find all the weather factors working in concerted action to increase the water loss. There are, as a rule, only a few days of this extreme character during a growing season. But when they do occur, corn is apt to suffer unless there is sufficient available moisture in the soil to supply the plant as rapidly as it is evaporated from the leaves and stems. At 2 p. m., July 27, the temperature was 105° F., the relative humidity was 14 per cent, and the wind velocity 12 miles per hour. In spite of these exacting conditions, the daily record shows little tendency on the part of the plant to diminish the rate of water loss as compared with the evaporation rate from a free-water surface. On those days when all of the weather factors do not act in one accord, some one or more of them are dominant and the water loss fluctuates according to these.

Table 6 and Chart V show the average daily transpiration, evaporation, and climatic factors during each of 10 weeks, from July 14 to September 19. There is a general tendency for transpiration to follow evaporation, as influenced by the weather conditions, but toward the end of the season when the plants begin to ripen and the functioning leaf area decreases, this relationship is practically lost.

Table 6.—*Weekly summary of weather factors and the average transpiration of 12 plants.*

Week ending	Water transpired per plant. (Av. 12 plants)	Water evaporated from free-water surface. (Av. 6 jars)	Mean hourly temperature. (7 a. m.-7 p. m.)	Mean relative humidity. (7 a. m.-7 p. m.)	Av. hourly wind velocity 10 ft. above ground. (7 a. m.-7 p. m.)
	Grams	*Grams*	*Degrees F.*	*Per cent*	*Miles*
July 18	1895	291	84.3	57.9	7.2
" 25	2188	274	84.3	47.2	6.3
August 1	3109	329	87.6	44.6	7.2
" 8	2126	192	78.4	49.4	5.0
" 15	2035	212	79.6	57.8	6.6
" 22	2029	166	83.7	64.2	4.4
" 29	1438	194	73.0	59.5	7.4
September 5	615	75	66.4	73.6	5.1
" 12	991	185	67.7	61.2	9.5
" 19	562	174	72.8	62.6	5.2

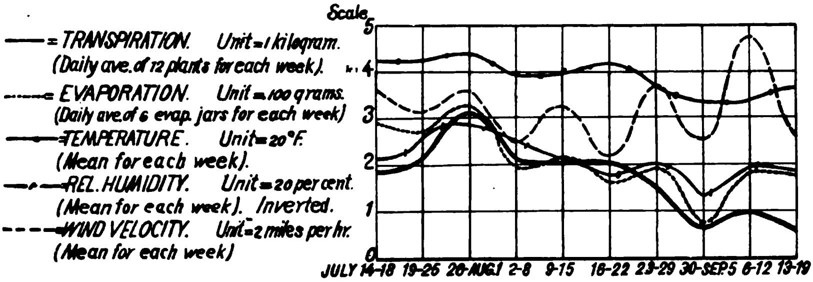


Chart V. Table 6 plotted.

In Table 7 and Chart VI are shown the average daily fluctuations for each of nine weeks, of the transpiration rate from plants in each of the five different degrees of soil moisture content. It will be noted that this variation from week to week is quite similar in all saturations excepting the lowest, or 35 per cent. Here the water supply was so low that when conditions became favorable for heavy transpiration the leaves simply wilted and rolled because the roots were unable to supply moisture to keep them turgid. Toward the end of the season when the weather became cooler, these extremely abnormal plants made a little extra growth and transpired proportionally more water. The general falling off in the quantity of water transpired toward the latter part of the season is due in part to the change in climate and in part to the gradual ripening of the corn.

TABLE 7.—*Weekly summary of the transpiration in five different degrees of soil moisture content.*

Week ending (7 p. m.)		Av. daily water transpired in 35 per cent saturation	Av. daily water transpired in 45 per cent saturation	Av. daily water transpired in 60 per cent saturation	Av. daily water transpired in 80 per cent saturation	Av. daily water transpired in 100 per cent saturation
		Grams	*Grams*	*Grams*	*Grams*	*Grams*
July	25	345	1128	1862	2357	2397
August	1	337	1764	2719	3345	3313
"	8	337	950	1870	2422	2072
"	15	349	886	1816	2370	1894
"	22	567	1260	1973	2232	1831
"	29	353	802	1349	1671	1247
September	5	236	381	719	666	410
"	12	492	856	1136	1097	656
"	19	187	369	601	695	335

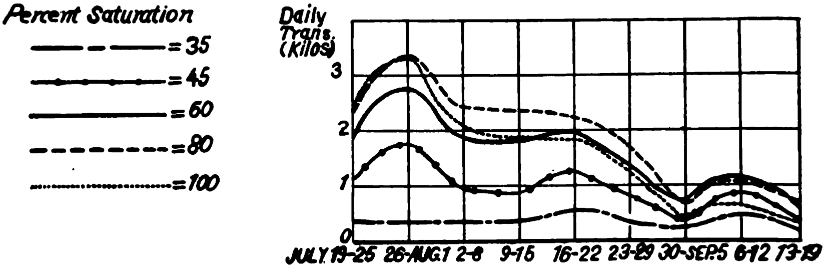


Chart VI. Table 7 plotted. Weekly summary of transpiration in five degrees of soil saturation.

SUMMARY

The optimum soil saturation for growth was from 60 to 80 per cent. The percentage of ear increased as saturation decreased down to 45 per cent, tho the largest actual weight of ear was produced at 60 per cent and the greatest total dry weight at 80 per cent.

Least water per gram dry weight was used in 45 to 60 per cent saturation. The percentage of leaf area to dry weight was least under the most nearly optimum conditions.

When the hourly fluctuation in evaporation of free water was compared with the transpiration of a corn plant, they were found to fluctuate in almost perfect accord, the transpiration tending neither to lag nor to accelerate. This indicates that "transpiration" is essentially "evaporation."

Transpiration records for daily or weekly periods gave similar results up until the latter part of the season, when plants began to ripen. Then evaporation exceeded transpiration.

The transpiration for the 12 hours of day was about 13 times greater than for the 12 hours of night.

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CORRELATION STUDIES OF CORN

By E. G. Montgomery

GENERAL DISCUSSION

In the selection and study of corn, correlation of character with yield has been a matter of interest for many years, the probable reason being that in corn more than in any other plant the individual plant is considered in the selection of seed. Almost every corn grower has some theory about the "shape" of ear or "type" of plant likely to give best yields. For example, many have favored a leafy plant, on the theory that the leaves being the seat of elaboration of carbohydrates an abundant supply of leaves would increase the yield of grain. Others have held that the ear should be produced low on the stalk, etc.

Few systematic studies have been made of the problem. Two methods of approaching the subject have developed, one being to take a representative number of plants by chance from a field, and by careful measurements attempt to find correlated relationships between parts. The second method is to take a certain character, such as height of ear, and select seed plants in which the character is present and, for comparison, other plants in which the character is absent.

By the first method A. A. Brigham,[1] in 1896, selected 200 plants of New England flint and made a very detailed study, attempting to find what characters of the plant might be associated with increased grain production. In general his study showed that an increase in grain production was accompanied by more or less of an increase in size in all parts of the plant. No significant correlation could be found by which one could judge the probable productivity of the plant. Ewing,[2] working with a yellow dent corn, endeavored to correlate characters at flowering time with final yield of the plant, but no important indicator of yield could be found at this time.

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[1] Brigham, A. A., Der Mais. Inaug. Diss. Göttingen, 1896.

[2] Cornell Bul. 289.

Several studies have been made by the second method. Professor Williams[1] has selected several contrasting pairs of ears and by comparison of yield is attempting to correlate the shape of ear with ability to yield.

At Nebraska[2] some study has been made of ear characters, in a similar manner. The study of ear characters so far is not conclusive, but indicates that the best yielder is probably a rather smooth type, with grain of only medium depth.

Smith[3] in studying the effect of continuous selection has compared such characters as high and low ears and erect and drooping ears. So far he has not found a difference in yield to necessarily follow a modification of the plant in one of these characters.

Statistical methods as a means of studying plant population promises to be of considerable value to plant breeders, and is attracting attention at this time. Two recent publications illustrating the use of statistical methods by plant breeders are Cornell Bullein No. 279, by Clark, on "Variation and Correlation in Timothy," and Illinois Bulletin 148 by Smith.

In 1902 the author, at the suggestion of Dr. T. L. Lyon, began the collection of data on corn with the purpose of determining if possible the relative value of some of the principal characters of the plant, and especially the relation these characters might bear to yield. The work has been continued since, and the data recorded in the following pages are summarized from the records.

2. A range of variations for one or more of the members.

3. The possibility of each member undergoing a change, more or less independently of other members.

Variation may consist in the dropping or adding of a member, as in barren plants compared with fertile plants; or, when retaining all the members, in the modification of one or all of them. Almost unlimited combinations of the modified members may be brought about.

VARIATIONS FOUND IN MAIZE PLANTS

Variability with *Zea mays* is so great that 6 groups and some 500 varieties are recognized.[1] The greatest variation is found in the size, shape, and character of kernel, and it is principally upon these modifications that the classification of varieties is based. The next greatest variation is in size of plant. In other characters, however, the genus is remarkably uniform, especially in type of leaf, type of stem, and the infloresence. All species and varieties intercross freely.

Within a group, such as dent corn or flint corn, usually the whole range of variation may be found in size of plant, color of grain, and shape of grain, tho there is a recognized limit in *character* of the grain, such as starchy endosperm, flinty endosperm, floury endosperm, or saccharous endosperm.

Within a recognized variety the variation in color of kernel is limited to one recognized color, or even shade of color, except where the grain is variegated, as in *calico* corn. There is always some recognized *type* of kernel for each variety, but a high degree of fluctuation in average weight and average length of kernel. This variation is in some measure inheritable, due partly to the mixed parentage of varieties and the lack of rigid selection to type, and partly to the influence on growth of local environment, which must, of course, vary in some degree with each individual.

---

[1] Sturdevant, Bul. 57, Office of Experiment Stations.

The causes of inherited variations in the plant are wrapped up in its historical development, concerning which very little is known. The temporary effect of climate in modifying the plant is shown in this paper by Table 5, and some of the effects of soil fertility are statistically demonstrated by Davenport (Principles of Breeding, p. 450).

It is a debated question whether the somatic variations caused by environment later become inheritable and capable of gametic transmission, or whether the variations are the result of the accumulation of smaller variations and natural selection, or, as some maintain, of mutations of greater or less degree and natural selection.

Whatever the original cause of characters, all types of corn are rich in variations, and it is probable that most of our recognized varieties are the result of artificial selection toward an ideal.

RESULTS OF INVESTIGATION OF CORRELATIONS IN THE CORN PLANT

The object of this investigation was to secure data on

(*a*) The correlation between parts of the corn plant, and the value of certain combinations of characteristics.

(*b*) The modifications which take place in the corn plant as a result of change in environment.

(*c*) The relations between the amount of water used, the leaf area, and growth in the corn plant.

During the years 1902, 1903, 1905, 1906, 1908, 1909, and 1910 notes were taken on a large number of individual corn plants. The following points have been observed and tabulated regarding each plant: leaf area, height of stalk, height of ear, number of nodes, ear nodes, length of shank, weight of stalk, weight of ear, total weight of plant, ratio of leaf area to total weight, ratio between weight of stalk and weight of ear, ratio of leaf area to weight of ear, ratio of leaf area to weight of stalk. For better comparison some of these data have been recalculated on the basis of each plant having a leaf area of 1,200 square inches.

While the above plan was adopted in 1902, the work has gone forward under many difficulties, partly because of the uncertainty of results obtained under field conditions, where it is impossible to control many elements of environment, and partly because many of the difficulties which might have been avoided could not be seen in time for avoidance.

METHODS.—In 1902 complete measurements were taken of forty plants, representing four varieties, ten typical plants being taken from each variety. The varieties used were Minnesota No. 13, Pride of the North, Hogue's Yellow Dent, and Golden Row. Notes were taken on the height of the plant, the node from which each ear grew, the number of nodes per plant, the height of ear from ground, and the area of each leaf. Each plant was labeled, and when fully ripe cut off at surface of ground and stored in a dry room. Weighings were taken December 20, 1902. The grain from each ear was shelled and weighed, the cob and leaves being weighed with the stalk. From these data the total weight of stalk was calculated, as was also the ratio of weight of ear to weight of stalk.

DETERMINING LEAF AREA.—In order to find a rapid means of determining leaf area a number of plants were taken and the leaves carefully measured for area. It was then found that if the length of the leaf was multiplied by the breadth of the leaf at the widest point and three-fourths of this product taken it gave approximately the leaf area. Following are the measurements in detail of one of these plants. Numbering begins at bottom of plant:

Leaf	Length	Breadth	Product of length by breadth	¾ length by breadth	Actual area
	Inches	*Inches*	*Sq. in.*	*Sq. in.*	*Sq. in.*
1........	41.0	4.75	194.7	146.0	146.0
2........	40.0	4.25	170.0	127.5	121.0
3	36.0	5.25	189.0	141.7	140.0
4........	32.0	3.75	120.0	90.0	93.0
5........	48.0	5.25	252.0	189.0	204.0
6	39.5	3.75	148.1	111.0	102.0
7........	34.0	4.50	153.0	114.7	112.0
8........	29.0	4.00	116.0	87.0	94.5
9........	39.0	3.50	133.0	99.7	96.5
Totals.	....	....	1631.8	1223.6	1227.0

The actual area was almost three-fourths of the product obtained by multiplying length by breadth. In a number of measurements made this method was found to be accurate within 2 per cent. Thus, by taking the length and breadth of leaves in the field, which could be rapidly carried out, it was possible to find the actual leaf area of each plant.

RECORDING FIELD NOTES

For taking notes in the field, a blank form was prepared which could be filled in with the desired data. These blanks were mimeographed and fastened on a letter file so that they could be carried in the field or filed for future reference. The following outline is a copy of the form usually used:

CORN.

No. .... **Date** ....

Name .... **Location** ....

H. S.	H. E.	N. N.	E. N.	N. A. E.	N. B. E.	L. Sh.	L. L. N.	A. L. N.	W. S.	W. E.	T. W.	R.	L. A.
1200 sq. in. per plant													

No. L.	L. L.	W. L.	E.	A.
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

REMARKS.

H. S.	Height Stalk.
H. E.	Height Ear
N. N.	Number Nodes.
E. N.	Ear Nodes.
N. A. E.	Nodes Above Ear.
N. B. E.	Nodes Below Ear.
L. Sh.	Length Shank.
L. L. N.	Length Lower Nodes.
A. L. N.	Average Length Nodes.
W. S.	Weight Stalk.
W. E.	Weight Ear.
T. W.	Total Weight of Plant.
R.	Ratio of Ear to Stalk.
L. A.	Leaf Area.

Results in 1902.—For 1902, only the data are presented regarding the relation of leaf area to weight of stalk and ear, the number of plants being too few to give valuable data on other characters.

Table 1 gives the data in detail as obtained on 36 plants. From this table it is evident that when individual plants are considered there is no marked relation between the leaf area and weight of corn produced or the total weight of plant. This is made more apparent by reducing all plants to a given basis in regard to leaf area and constructing the table on this basis, taking 1,200 square inches, which is about the average leaf area for a plant, and recalculating the data for each plant, but maintaining the relationship between leaf area and other parts the same. Table 2 has been reconstructed on this plan. This shows very clearly that even for the same variety, such as Hogue's Yellow Dent, with a given leaf area of 1,200 square inches the weight of ear may vary from 100 grams to 295 grams, while the total weight may vary from 342 grams to 540 grams. In the different varieties it was found that there was quite a difference in the ratio of corn to stalk as is shown by Table 3. The ratio between the leaf area and total weight of dry matter produced or weight of ear varied to some extent. The amount of leaf area to one gram of dry weight varies from 2.30 square inches, with Minnesota No. 13, to 2.66 square inches, with Hogue's Yellow Dent, when total weight of plant was considered; or from 4.39 square inches, for Pride of the North, to 5.73 square inches, for Hogue's Yellow Dent, when relation of leaf area to weight of ear was considered. It was also noted that the largest two varieties of corn, Hogue's Yellow Dent and Golden Row, had relatively more leaf area than the smallest two, Minnesota No. 13 and Pride of the North. These data, however, can only be considered as preliminary, since the number of plants used in each case was too small to give conclusive data. In selecting the plants, care was taken to find typical plants, and only plants bearing a fair-sized ear were taken. The data are sufficiently general so that at least it may be said that there are differences in the relation of leaf area to weight of dry matter produced in different varieties, and there are indications, also, that when individuals are considered there is no very close correlation between leaf area and dry matter produced.

TABLE 1.—*Detailed data on 36 corn plants, showing relation of air-dry weights to leaf area, 1902.*

HOGUE'S YELLOW DENT

Plant No.	Weight of ear	Weight of stalk	Ratio wt. stalk to wt. ear	Leaf area	Total weight
	Grams	*Grams*		*Sq. in.*	*Grams*
1	294	212	0.72	1,190	506
2	164	212	1.30	1,220	376
3	223	270	1.21	1,270	493
4	276	279	1.00	1,312	555
5	185	278	1.50	1,250	463
6	281	223	0.79	1,202	504
7	188	285	1.50	1,295	473
8	156	255	1.27	1,865	411
9	264	245	1.30	1,350	509
10	270	208	0.77	1,250	478
Average	230	246	1.15	1,320	476
GOLDEN ROW					
11	315	333	1.05	1,425	648
12	244	246	1.00	1,440	490
13	280	289	1.00	1,358	569
14	184	137	0.70	1,025	321
15	307	195	0.63	1,009	502
16	222	288	1.30	1,325	510
17	313	364	1.10	1,715	677
18	285	264	0.93	1,317	549
19	196	160	0.81	1,107	356
20	355	274	0.77	1,342	629

TABLE 1.—*Continued.*

PRIDE OF THE NORTH

Plant No.	Weight of ear	Weight of stalk	Ratio wt. stalk to wt. ear	Leaf area	Total weight
	Grams	*Grams*		*Sq. in.*	*Grams*
21	146	120	0.82	797	266
22	163	195	0.58	685	358
23	181	110	0.60	620	291
24	....	....	....	....	....
25	225	218	0.96	967	443
26	215	170	0.79	867	385
27	227	160	0.70	925	387
28	158	120	0.76	802	278
29	145	96	0.66	703	241
30	172	117	0.68	758	289
Average	181	145	0.74	795	326

MINNESOTA NO. 13.

Plant No.	Weight of ear	Weight of stalk	Ratio wt. stalk to wt. ear	Leaf area	Total weight
31	....	....	....	....	....
32	134	197	1.47	694	331
33	204	200	1.00	976	404
34	181	155	0.85	699	336
35	....	....	....	....	....
36	123	175	1.40	727	298
37	154	110	0.71	642	264
38	184	130	0.70	770	314
39	171	180	1.06	758	351
40	....	....	....	....	....
Average.	164	164	1.00	752	328

TABLE 2.

	a recalculated to basis of 1,200 square inches per plant.				*Actual leaf area and weight of plants.*			
				HOGUE'S YELLOW DENT				
lant No.	Leaf area	Weight of ear	Weight of stalk	Total weight of plant	Leaf area	Weight of ear	Weight of stalk	Total weight plant
	Sq. in.	*Grams*	*Grams*	*Grams*	*Sq. in.*	*Grams*	*Grams*	*Grams*
....	1,200	100	164	264	1,865	156	255	471
....	1,200	161	208	369	1,220	164	212	376
....	1,200	245	200	420	1,320	270	208	478
....	1,200	178	269	436	1,295	188	285	473
....	1,200	177	267	444	1,250	185	278	463
....	1,200	210	254	464	1,270	223	270	493
....	1,200	281	223	504	1,202	281	223	504
....	1,200	254	255	509	1,312	276	279	555
....	1,200	295	214	509	1,190	294	212	506
....	1,200	234	306	540	1,350	263	245	509
				MINNESOTA NO. 13.				
....	1,200	202	254	456	727	123	175	298
....	1,200	287	203	490	770	184	130	314
....	1,200	250	245	495	976	204	200	404
....	1,200	290	206	496	642	154	110	264
//////	1,200	233	342	575	694	134	197	331
....	1,200	310	266	576	699	181	155	336

TABLE 3.—*Relation of air-dry weight to leaf area in four varieties, 1902.*

Variety	Weight of ear	Weight of stalk	Ratio wt. stalk to wt. ear	Total weight	Leaf area
	Grams	*Grams*		*Grams*	*Sq. in.*
Hogue's Yellow Dent......	230	265	1.15	496	1,320
Golden Row...............	270	255	0.94	525	1,306
Minnosota No. 13..........	164	164	1.00	328	752
Pride of the North.........	181	134	0.74	315	795

Variety	Ratio leaf area (sq. ins.) to total weight (grams)	Ratio leaf area (sq. ins.) to wt. ear (grams)
Hogue's Yellow Dent	2.66	5.73
Golden Row	2.50	4.84
Minnesota No. 13	2.30	4.59
Pride of the North	2.52	4.39

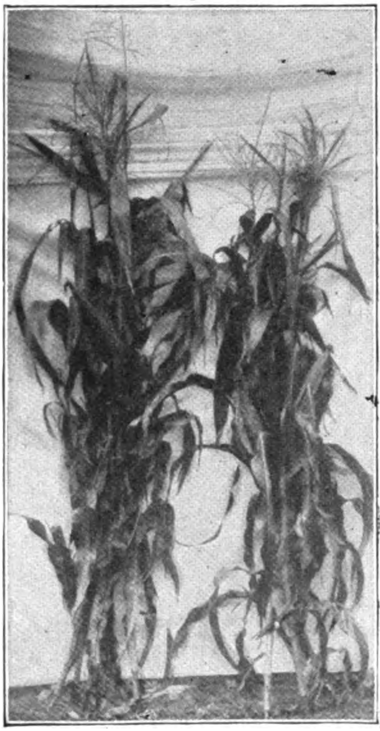
RESULTS IN 1903.—In 1903 it was planned to continue the preliminary work. A number of varieties of corn were being grown in experimental plats to test the effect of acclimatization upon the corn plant, and four of these varieties were selected for study; also, about 100 plats of corn were being grown, each plat being from a single ear of Hogue's Yellow Dent corn. Twelve of these plats were selected for study, and ten stalks in each plat were carefully measured as in the previous year. The following is the list of varieties and plats studied in 1903:

Field	Plat	Variety	Origin
E	2	Reid's Yellow Dent..........	Illinois
E	3	Reid's Yellow Dent..........	Nebraska
E	4	Snowflake White	Iowa
E	5	Snowflake White	Nebraska
E	6	Early Yellow Rose...........	Iowa
E	7	Early Yellow Rose...........	Nebraska
E	13	Iowa Gold Mine	East Nebraska
E	14	Iowa Gold Mine	Central Nebraska
I	13	Hogue's Yellow Dent..	Nebraska
I	14	Hogue's Yellow Dent........	Nebraska
I	15	Hogue's Yellow Dent........	Nebraska
I	16	Hogue's Yellow Dent........	Nebraska
J	9	Hogue's Yellow Dent........	Nebraska
J	11	Hogue's Yellow Dent........	Nebraska
J	12	Hogue's Yellow Dent........	Nebraska
J	13	Hogue's Yellow Dent........	Nebraska
J	21	Hogue's Yellow Dent	Nebraska
J	28	Hogue's Yellow Dent........	Nebraska
J	29	Hogue's Yellow Dent........	Nebraska
J	70	Hogue's Yellow Dent........	Nebraska

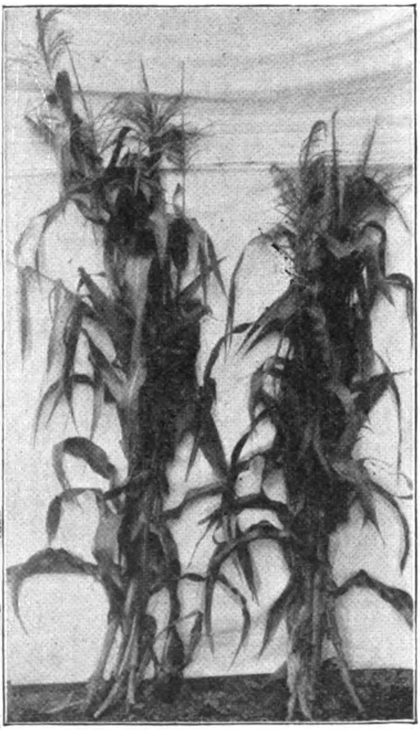
Plat 2, Reid's Yellow Dent from Illinois, was obtained from James Reid & Company, Delavan, Illinois, while Plat 3, Reid's Yellow Dent of Nebraska, had been procured from the same place two or three years previously, but grown in Nebraska since. The Snowflake White corn, on Plats 4 and 5, and Early Yellow Rose corn, on Plats 6 and 7, were originally obtained from J. B. Armstrong & Sons of Shenandoah, Iowa. That which is indicated as Nebraska grown was obtained in the spring of 1901 and grown in central Nebraska during the seasons of 1901 and 1902. This seed was then brought to the Experiment Station and new seed was obtained from Armstrong & Sons in the spring of 1903 to grow in comparison with this. The Iowa Gold Mine grown on Plat 13 had been grown for a number of years in Washington County, Nebraska, while the Iowa Gold Mine on Plat 14 had been grown continuously in Kearney County, Nebraska. These two were grown in order to note the effect of the climate of eastern and central Nebraska on the corn plant. The general data are given in detail in Table 4. Comparison of the varieties shows considerable difference in some characters.

LE 4.—*Summary of data secured on 10 average plants from 20 plats of corn to show average variation in certain characters, 1903.*

Variety	Origin	Length shank	Height stalk	Height ear	Number nodes	Ear node	Weight stalk	Weight ear	Total weight	Ratio wt. stalk to wt. ear	Leaf area	Ratio leaf area to wt. stalk	Ratio leaf area to wt. ear	Ratio leaf area to total wt.	Basis leaf area 1200 sq. in. Wt stalk	Wt. ear	Total wt.
(2)	(3)	(4) *In.*	(5) *In.*	(6) *In.*	(7)	(8)	(9) *Gms.*	(10) *Gms.*	(11) *Gms.*	(12)	(13) *Sq. In.*	(14)	(15)	(16)	(17)	(18)	(19)
Reid's Yellow Dent..................	Ill.	4.9	105.1	46.0	14.1	7.9	191.8	249.5	441.3	.77	1,260.0	6.56	5.04	2.86	182.6	238.8	416.4
Reid's Yellow Dent..................	Nebr.......	5.2	101.7	45.3	13.3	7.6	172.5	234.4	406.9	.74	1,167.1	6.77	4.98	2.88	176.9	239.7	416.6
Snowflake White....................	Iowa	7.4	100.3	43.5	13.7	7.7	266.5	303.7	570.2	.88	1,262.3	4.77	4.15	2.22	250.0	289.4	539.4
Snowflake White....................	Nebr.......	5.5	89.2	34.7	12.5	6.8	202.5	269.4	471.9	.75	1,066.5	5.23	3.91	2.24	230.7	310.2	540.9
Early Yellow Rose..................	Nebr.......	5.3	92.9	37.7	12.6	6.8	174.0	238.8	412.8	.73	1,001.7	5.75	4.17	2.41	208.7	289.7	498.4
Early Yellow Rose..................	Iowa	7.4	96.2	38.7	13.0	7.1	229.7	235.5	465.5	.97	1,035.8	4.53	4.37	2.23	263.2	276.0	539.2
Iowa Gold Mine....................	East Nebr.	5.5	93.0	40.7	12.7	7.1	166.4	240.6	407.0	.69	1,072.4	6.41	4.44	2.62	188.1	271.1	459.8
Iowa Gold Mine....................	Cent. Nebr.	6.4	88.7	33.9	12.1	6.2	182.6	240.7	423.3	.76	928.6	5.07	3.86	2.19	237.1	311.0	548.1
Single ear of Hogue's Yellow Dent.	Nebr.......	3.9	84.7	39.6	13.7	7.4	180.5	209.5	390.0	.86	1,086.0	5.98	5.19	2.78	201.9	230.6	432.5
Single ear of Hogue's Yellow Dent.	Nebr.......	4.4	92.1	37.4	13.6	7.1	183.0	231.2	414.2	.79	1,139.5	6.17	4.88	2.72	196.3	249.3	445.6
Single ear of Hogue's Yellow Dent.	Nebr.......	4.7	84.8	34.9	12.0	6.6	173.0	193.4	366.4	.89	869.2	5.07	4.47	2.38	234.3	269.6	503.9
Single ear of Hogue's Yellow Dent.	Nebr.......	4.1	95.9	41.7	13.9	8.2	190.6	258.1	448.7	.76	1,109.6	5.79	4.27	2.46	208.3	283.1	491.4
Single ear of Hogue's Yellow Dent.	Nebr.......	5.7	93.8	39.0	12.3	6.9	220.1	271.6	491.7	.81	1,038.7	4.76	3.82	2.12	249.8	318.6	568.4
Single ear of Hogue's Yellow Dent.	Nebr.......	3.8	90.5	40.1	12.6	7.1	173.7	246.0	419.7	.70	1,007.3	5.79	4.09	2.39	208.1	293.4	501.5
Single ear of Hogue's Yellow Dent.	Nebr.......	5.6	94.0	41.4	14.2	7.8	258.2	300.8	559.0	.86	1,398.6	5.41	4.66	2.68	222.0	257.3	479.0
Single ear of Hogue's Yellow Dent.	Nebr.......	5.0	84.8	37.0	13.4	7.4	215.9	278.3	494.2	.78	1,207.8	5.58	4.38	2.44	215.7	277.5	493.2
Single ear of Hogue's Yellow Dent.	Nebr.......	4.8	92.7	39.9	13.3	7.2	198.5	252.7	451.2	.78	1,179.7	5.97	4.69	2.63	200.3	254.7	455.0
Single ear of Hogue's Yellow Dent.	Nebr.......	6.4	98.1	44.2	13.8	7.7	264.4	246.8	511.2	1.07	1,297.3	4.91	5.26	2.54	244.0	228.2	472.2
Single ear of Hogue's Yellow Dent.	Nebr.......	6.6	98.5	45.2	13.9	7.8	313.7	297.0	610.7	1.06	1,372.2	4.35	4.59	2.23	277.4	262.9	540.3
Single ear of Hogue's Yellow Dent.	Nebr.......	4.6	97.0	48.0	12.9	8.0	176.3	236.7	413.0	.74	1,141.7	6.47	4.82	2.76	185.4	248.8	434.2



Iowa Gold Mine, grown at the Nebraska Experiment Station in 1903, showing the effects of adaptation. The bunch on the left was grown from seed directly from Iowa, while that on the right was from seed which had been grown in Nebraska two years. (Reprinted from Bulletin 91.)



Snowflake White, grown at the Nebraska Experiment Station in 1903, showing the effects of adaptation. The taller bunch was grown from seed directly from Iowa, while the shorter was grown from seed which had been grown in Nebraska two years. (Reprinted from Bulletin 91.)

EFFECT OF ACCLIMATIZATION

The study of the effect of acclimatization is especially interesting, and the following data taken from Table 4 gives us a comparison of the two varieties, Snowflake White and Early Yellow Rose, when the seed is grown under Nebraska and Iowa conditions:

TABLE 5.—*Comparison of two varieties when the seed was grown under Iowa and Nebraska conditions.*

	Snowflake White		Early Yellow Rose	
	Iowa	Nebraska	Iowa	Nebraska
Height of stalk	100.3 ins.	89.2 ins.	96.2 ins.	92.9 ins.
Height of ear	43.5 ins.	34.7 ins.	38.7 ins.	37.7 ins.
Length of shank	7.4 ins.	5.5 ins.	7.4 ins.	5.3 ins.
Number leaves	13.7 ins.	12.5 ins.	13.0 ins.	12.6 ins.
Ear node	7.7	6.8	7.1	6.8
Weight of stalk	266.5 gms.	202.5 gms.	229.7 gms.	174.0 gms.
Weight of ear	303.7 gms.	269.4 gms.	235.5 gms.	238.8 gms.
Total weight	570.2 gms.	471.9 gms.	465.2 gms.	412.8 gms.
Ratio weight stalk to weight ear	.88	.75	.97	.73
Leaf area	1,262.3 sq. in.	1,066.3 sq. in.	1,035.8 sq. in.	1,001.7 sq. in.
Ratio leaf area to total weight	2.22	2.24	2.23	2.41
Yield per acre	68.7 bush.	73.7 bush.	62.1 bush.	68.1 bush.
Basis 1,200 sq. in. leaf area				
Weight stalk	250.0 gms.	230.7 gms.	263.2 gms.	208.7 gms.
Weight ear	289.4 gms.	310.2 gms.	276.0 gms.	289.7 gms.
Total weight	539.4 gms.	540.9 gms.	539.2 gms.	498.4 gms.

It will be noted that the corn grown from Iowa seed was somewhat taller, the ear produced slightly higher, and the ear shank about two inches longer, while the corn grown in Nebraska for two years had evidently lost an average of about one leaf per stalk. The total weight of plants was less with the Nebraska corn, as was also the leaf area. If the data are reduced to a basis of 1,200 sqaure inches per plant, some of the points can be brought out more clearly. It will be noted that for an equal leaf area the Iowa corn had a heavier stalk and lighter ear than the Nebraska corn, as is also shown by the ratio of stalk to ear, while in actual weight the Iowa ear was heavier. In yield per acre, the Nebraska corn gave best results. Similar results were obtained with the Reid's Yellow Dent from Illinois and Nebraska (see Table 5), also with the Iowa Gold Mine from eastern and central Nebraska, but the differences were not so marked as with the Snowflake White and the Early Yellow Rose.

VARIATION IN PLANTS FROM SINGLE EARS

In the study of plats from single ears of Hogue's Yellow Dent corn it will be noted that there were considerable differences (Table 4). For example, the leaf area in Plat 15, Field I, was 869 square inches, while in Plat 12, Field J, it averaged 1,398 square inches. The relation of leaf area to total weight of dry matter varied from 2.12 to 2.75 square inches of leaf area to one gram dry matter; or on a basis of 1,200 square inches, which is about the leaf area of the average plant, the amount of dry matter would vary from 434 grams to 563 grams. The ratio of stalk to ear also varied from .70 to 1.07. Other variations were in about the same degree.

A complete tabulation was made of all 1903 data, arranging the plants in classes of ten, according to variation, under each character, for comparison. Notwithstanding the rather small number of plants considered in 1903, most of the conclusions drawn from these data were verified in 1905, when a larger number was used and more care exercised in having all plants grown under uniform conditions.

Data Recorded and Method in 1905.—Again using the same variety, Hogue's Yellow Dent, in 1905, observations were taken on 404 plants in Field "C." The first 136 plants, that is, Nos. 5-1 to 5-136, were grown one in a place, three feet eight inches apart each way. The rest of the plants, Nos. 5-137 to 5-404, were plants growing two plants in a place with hills three feet eight inches apart. Tillers were removed from all plants when small. In a general way, the results confirm those of 1903, except that the range of variation is a little greater.

VARIATION AND CORRELATION

Leaf Area.—Table 6 gives a summary of leaf area for 342 plants. While over 400 plants were measured originally, about 60 were injured in some way before the final data could be taken. The plants were divided into groups, with an average difference of 100 square inches leaf area for each group. The variation was from 927 to over 1,900 square inches.

Relative Leaf Area.—Table 6 shows a summary of the principal characters tabulated in relation to leaf area, while Table 7 is a correlation array for leaf area and total weight, also giving the frequency distribution for these two characters. There is a fair degree of correlation between leaf area and total weight (0.584), or weight of stalk (0.578), but rather low degree when weight of ear is considered (0.386). It seems probable that stalk and leaf would show a closer relationship in growth than leaf and ear, as the latter is in a sense a product of these parts.

Weight of Plant.—Table 8 shows the total weight of the plant to vary from about 375 grams to 963 grams, while Table 7 and Table 9 show the frequency distribution of the plants according to total weight.

The highest degree of correlation is between total weight and leaf area, 0.584, but this is not close, as is shown in column 6, Table 8, which gives the relative number of square inches of leaf area to one gram weight. This varies from 3.10 to 1.72; that is, with a given leaf area one plant may be almost twice as heavy as another.

It would appear here that the small plants have a greater relative leaf area.

LARGE AND SMALL PLANTS HAVE ABOUT THE SAME PROPORTION OF EAR AND STALK.—In Table 8, column 7, with the exception of the first case (which contains plants almost barren), there is no marked difference in proportion of ear to stalk, the stalk on the average having about two-thirds the weight of the ear. This might not be true if large and small varieties were compared—small varieties usually having a higher proportion of ear.

WEIGHT OF EAR.—Table 10 is a summary of plants arranged according to weight of ear and Table 11 shows the various correlation coefficients. Weight of ear is the most interesting character from a practical standpoint, since it is an indication of productiveness. It will be seen from Table 11 that there are no high correlations, indicating that variation in size of ear is met with only small corresponding changes in other parts of the plant.

RELATIVE VERSUS ACTUAL PRODUCTIVENESS.—If the relative size of ear produced, rather than the *actual* size, be used as a measure of productivity then Table 2 offers an opportunity to study the characters of some productive and nonproductive plants. In the first three cases the ear is about twice the weight of the stalk but in the last three the stalk is heaviest, yet the total weight of plant remains about constant. A study of the data does not show a marked change in other characters of the plant to correspond. In Table 10, where the same plants are arranged according to *actual* yield per plant, the increased size of ear is accompanied by some increase in all parts of the plant.

There is no close relationship between any character of the plant and productiveness as judged either by the actual or by the relative size of ear. If characters were closely correlated, when one increased all would increase in the same way, but we see in most cases under average field conditions that if some one character be increased the other characters of the plant, instead of being increased in the same relative proportion, are relatively increased 20 to 40 per cent, these being growth correlations, and none of them closely bound. This would indicate that any particular character of the plant might be modified without greatly affecting other characters. Conversely the attempt to influence a second character by selection of some corollary would have very little influence. This especially applies to actual or relative size of ear.

The only general exception to the above is the relation between height of ear and height of stalk (0.64) where a selection for high or low ear would be followed by a marked change in height of stalk.

To fully verify the above conclusions, however, it would be desirable to check results by the second method, previously mentioned (p. 109), namely, to select contrasting pairs of characters and make comparative tests.

Also, in another variety of corn, correlations might be found which were not present in the variety under consideration.

HEIGHT OF EAR.—An increase in height of ear, as shown by Table 13 and Table 14, is accompanied by a marked increase in height of stalk, and more or less increase in other parts of the plant except length of shank, which character shows an actual decrease. The lower ears are a little above the sixth node and the upper ears a little above the eighth. From a study of the correlations, increased height of ear is more closely related to an increased vegetative growth than to an increased size of ear.

HEIGHT OF STALK.—Height of stalk varied from about 85 to 130 inches. Table 16 shows no marked correlation except in relative height of ear.

SLENDER VERSUS STOUT PLANTS.—By dividing the weight of a stalk by its height we would secure a factor giving the relative weight per inch of height. Table 15 shows the plants arranged according to this factor. The weight per inch varies from 1.25 grams to 4.85 grams. As relative weight increases, there is no marked change in height of plant or number of nodes, but a marked increase in length of ear shank.

The *actual* size of ear increases as the stalks become stouter, up to a point somewhat above average, but the relative proportion of ear decreases.

TABLE 6.—*Summary: Plants arranged in groups according to leaf area, 1905.*

	No. of analyses	Leaf area	Height stalk	Height ear	Number nodes	Ear node	Length shank	Weight stalk	Weight ear	Total weight	Ratio of area to total wt.	Ratio wt. stalk to wt. ear
(1)	(2)	(3) *Sq in.*	(4) *Inches*	(5) *In.*	(6)	(7)	(8) *Inches*	(9) *Grams*	(10) *Grams*	(11) *Grams*	(12)	(13)
elow 1,000....	10	927.8	98.8	36.9	11.8	5.9	6.4	174.0	287.0	461.0	2.01	.61
000-1,100 ...	23	1,056.9	96.7	37.3	12.4	6.6	6.6	193.3	311.3	504.6	2.09	.62
100-1,200	32	1,152.2	101.3	40.8	13.1	7.4	6.7	215.0	317.5	532.5	2.16	.68
200-1,300	54	1,248.6	101.2	42.2	13.4	7.8	7.1	236.1	335.2	571.3	2.19	.70
300-1,400	63	1,352.0	104.4	43.4	13.6	7.6	8.0	274.3	376.8	651.1	2.09	.66
400-1,500	65	1,451.0	108.5	45.7	14.2	8.0	8.0	267.0	408.2	575.2	2.15	.65
500-1,600	33	1,551.5	107.7	46.6	14.3	8.0	8.6	298.8	390.9	689.7	2.25	.76
600-1,700	33	1,648.3	108.8	47.5	15.0	8.3	8.0	315.3	412.1	727.4	2.27	.76
700-1,800 ...	18	1,747.8	108.8	47.8	15.2	8.2	9.5	317.2	445.3	762.5	2.29	.71
800 and over.	11	1,912.9	115.6	52.6	15.7	9.1	8.2	345.0	413.4	758.4	2.52	.83

TABLE 7.—*Correlation between leaf area and total weight.*

LEAF AREA

700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	1900	1950	2000	2050	2100	2150	
											1																			1
							1																							1
											1																			1
					1	1	1		1		1				1															7
					1	2	3	3	2		1			1		1														14
				2		1	1	6	4	2		5	1		1			1												24
						2	4	1		6	6	3	8	2		2	2	4	1					1						42
					1	1	1	1	5	11	8	5	4	3	4	3	3	1	2	2	1				1					57
								1	3	4	6	5	4	10	6	9	2	1	1	1										53
							2	1			2	4	5	4	6	4	3	3	2	3	2	2							1	44
										3		2	5	3	3	2	1	3	2	2	1									27
											1		4	4	2	2	2	1	4	1	1		1		1	1				25
							1						1	3	2	4	1		2	4	2	1			1					22
													1		1	2	4					1	1							10
														1				3						1		1				6
													1					1		1		1								4
															1					1		2								4
0	0	0	0	2	3	7	14	13	15	26	27	24	34	31	27	29	18	18	14	15	7	7	2	2	3	2	0	0	1	342

Correlation between leaf area and total weight	.584 ± .024
Correlation between leaf area and height of stalk	.382 ± .031
Correlation between leaf area and weight of stalk	.578 ± .024
Correlation between leaf area and height of ear	.435 ± .030
Correlation between leaf area and number of nodes	.622 ± .022
Correlation between leaf area and weight of ear	.386 ± .032

8.—*Summary: Plants arranged in classes according to total weight, 1905.*

of l- s	Total weight	Weight stalk	Weight ear	Ratio leaf area to total wt.	Ratio wt. stalk to wt. ear	Leaf area	Height stalk	Height ear	Number nodes	Ear node	Length shank
	(3) *Grams*	(4) *Grams*	(5) *Grams*	(6)	(7)	(8) *Sq. in.*	(9) *Inches*	(10) *Inches*	(11)	(12)	(13) *Inches*
	357.5	182.0	175.5	3.10	1.04	1,106.8	95.2	37.1	13.0	7.0	4.2
	423.2	169.0	254.2	2.66	.66	1,127.8	100.6	39.1	13.0	6.9	5.3
	474.0	190.2	283.8	2.50	.67	1,184.5	99.3	41.0	13.0	7.3	6.2
	524.8	220.5	304.3	2.52	.72	1,320.4	101.9	42.6	13.4	7.6	7.2
	571.8	229.6	342.2	2.33	.67	1,333.2	102.5	42.1	13.7	7.6	7.0
	620.9	256.6	364.3	2.22	.70	1,379.0	106.9	45.6	13.8	7.8	7.7
	673.1	283.0	390.1	2.20	.72	1,478.2	109.9	46.0	14.1	7.8	8.3
	723.7	305.2	418.5	2.01	.73	1,456.1	107.3	46.0	14.3	8.2	8.6
	770.0	320.2	449.8	2.01	.71	1,546.5	105.2	44.1	14.3	7.8	9.2
	814.5	322.3	492.2	1.92	.65	1,566.8	113.1	48.9	14.4	8.2	9.5
	871.5	321.5	550.0	1.79	.58	1,562.2	110.4	45.3	14.4	8.0	9.0
	963.7	373.6	590.1	1.72	.63	1,659.4	106.9	44.8	14.3	8.0	9.9

TABLE 9.—*Correlation between total weight and ear node.*

	EAR NODE								
	4	5	6	7	8	9	10	11	
225					1				1
275			1						1
325					1				1
375			3	3		1			7
425	1	2	2	3	4	2			14
475		1	6	5	9	2	1		24
525		1	4	15	15	6	1		42
575		2	4	19	23	7	1	1	57
625			7	12	21	12	1		53
675		1	3	16	13	7	4		44
725			1	7	9	6	3	1	27
775			2	10	6	6	1		25
825			1	5	8	5	3		22
875				3	4	3			10
925				1	2	2	1		6
975				2	2				4
1025			1		2	1			4
	1	7	35	101	120	60	16	2	342

Correlation between total weight and height of stalk................	.314 ± .033
Correlation between total weight and weight of ear	.847 ± .010
Correlation between total weight and leaf area	.584 ± .024
Correlation between total weight and number of nodes..............	.378 ± .031
Correlation between total weight and ear node...................	.023 ± .035

TABLE 10.—*Summary: Plants arranged in classes according to weight of ear.*

	No. of analyses	Weight ear	Weight stalk	Total weight	Ratio leaf area to total weight	Ratio weight stalk to wt. ear	Leaf area	Height stalk	Height ear	Number nodes	Ear node	Length shank
(1)	(2)	(3) *Grams*	(4) *Grams*	(5) *Grams*	(6)	(7)	(8) *Sq. in.*	(9) *Inches*	(10) *Inches*	(11)	(12)	(13) *Inches*
Below 200..	12	137.5	263.7	401.2	3.14	1.92	1,259.8	99.7	37.3	13.5	7.2	5.6
200-250.....	11	222.7	233.7	456.4	2.90	1.05	1,325.2	106.2	44.6	13.5	6.5	6.6
250-300.....	39	261.3	223.8	485.1	2.59	.86	1,251.2	100.9	41.3	13.4	7.3	7.1
300-350.....	78	324.0	241.5	565.5	2.34	.74	1,324.5	103.9	42.8	13.5	7.5	7.3
350-400.....	84	367.3	265.9	633.2	2.22	.72	1,404.4	107.0	44.7	13.8	7.5	8.3
400-450.....	50	419.7	264.1	683.8	2.11	.63	1,443.3	107.5	45.9	14.4	8.5	7.6
450-500.....	28	468.7	285.2	753.9	1.95	.61	1,471.1	106.3	45.2	14.0	7.9	8.4
500-550.....	23	524.0	292.0	816.0	1.93	.56	1,571.3	109.1	48.2	14.5	8.4	8.3
550 and over	18	612.5	306.7	919.2	1.70	.50	1,561.2	107.7	44.1	14.4	7.8	9.4

TABLE 11.—*Correlation between weight of ear and leaf area.*

Leaf Area																														
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	1900	1950	2000	2050	2100	
																1														1
										1		1							1											3
								1				2							1											4
						1	2	1			1	1			1	1	1								1					10
1								1	3	6	2		2				1	3		1										20
					1	1	3	7	6		6	6	7	8	4	2	3	2	2	3	1	2	1			1				66
					1	1	1	2	2	6	10	9	9	7	12	5	10	3	6	1	3	1					1		1	91
							1		1	1	5	7	4	7	4	8	3	5	3	3	3		2	1						58
								1	1	1	2		2	6	4	5	3	1	2	3	4	1				1				37
								1				1		3	3	3	4		1	2	1	3		1	1					24
														1	2		4	3		1	1		2			1	1			16
														1		1					1		1							4
														1	1			1	2				1							6
																1					1									2
1	0	0	0	0	2	3	7	14	13	15	26	27	24	34	31	27	29	18	18	14	15	7	7	2	2	3	2	0	1	342

Correlation between weight of ear and leaf area	.386 ± .032
Correlation between weight of ear and height of stalk	.208 ± .035
Correlation between weight of ear and weight of stalk	.261 ± .034
Correlation between weight of ear and height of ear	.211 ± .035
Correlation between weight of ear and number of nodes	.248 ± .034
Correlation between weight of ear and ear node	.205 ± .035
Correlation between weight of ear and length of shank	.223 ± .035

TABLE 13.—*Summary: Plants arranged in classes according to height of ear, 1905.*

(1)	No. of analyses (2)	Height ear (3) *Inches*	Height stalk (4) *Inches*	Leaf area (5) *Sq. in.*	Length shank (6) *Inches*	Ear node (7)	Number nodes (8)	Total weight (9) *Grams*	Weight stalk (10) *Grams*	Weight ear (11) *Grams*
w 30	10	26.6	94.9	1,122.5	9.4	6.1	12.4	563.0	283.5	279.5
5	23	32.6	95.9	1,257.8	7.8	6.3	13.0	562.4	228.7	333.7
0	60	37.4	98.3	1,298.5	7.5	6.8	13.0	616.5	246.0	370.5
5	84	41 8	102.7	1,371.3	8.1	7.6	13.6	606.1	251.6	354 5
0	88	46.9	106.8	1,438.7	8.7	8.0	14.1	650.9	261.5	389.2
nd over	76	52.1	114.6	1,527.4	7.2	8.6	14.5	692.8	285.5	407.3

TABLE 14.—*Correlation between height of ear and length of shank.*

	LENGTH OF SHANK														
	.5- 1.9	2.0- 3.4	3.5- 4.9	5.0- 6.4	6.5- 7.9	8.0- 9 4	9.5-10.9	11.0-12.4	12.5-13.9	14.0-15.4	15.5-16.9	17.0-18.4	18.5-19.9	20.0-21.4	
2-24						2									2
5-27		1				1	1		1						4
8-30					1		1	1	1	1					5
1-33	1	1	1	5	3	2	1		1		1				16
4-36		3	1	3	5	4	1	1	1	1					20
7-39		3	3	11	5	10	6	7				1			46
0-42		2	7	6	12	13	4	6	1	1	1				53
3-45		3	2	11	8	13	2	7		4					50
6-48		2	7	12	8	7	5	8	2	3	1			1	56
9-51		1	4	8	4	10	4		3						34
2-54		1	4	8	4	7	1	1	2	2					30
5-57			4	2	4		2	1							13
8-60		1	2	1	1	2									7
1-63				1				1							2
4-66								1							2
7-69					1										1
	1	18	35	68	56	72	28	34	12	12	3	1	0	1	341

orrelation between height of ear and length of shank	.054 ± .036
orrelation between height of ear and number of nodes	.457 ± .029
orrelation between height of ear and weight of ear	.211 ± .035
orrelation between height of ear and leaf area	.435 ± .030
orrelation between height of ear and height of stalk.....	.640 ± .022

15.—*Summary: Plants arranged in classes according to ratio of weight of stalk to height.*

	Weight stalk	Weight ear	Total Weight	Ratio wt. stalk to height stalk	Leaf area	Height stalk	Height ear	Number nodes	Ear node	Length shank	No. in each class
(1)	(2) *Grams*	(3) *Grams*	(4) *Grams*	(5)	(6) *Sq. in.*	(7) *Inches*	(8) *Inches*	(9)	(10)	(11)	(12)
.4	148.0	232.0	380.0	1.39	1,131.0	106.0	35.0	12.6	6.3	4.5	3
	165.4	289.6	455.0	1.47	1,134.0	112.0	40.4	13.5	7.0	6.2	11
	176.0	332.0	508.0	1.70	1,183.0	103.0	44.5	13.3	7.5	6.2	82
	198.5	344.0	542.7	1.91	1,313.7	104.0	43.5	13.6	7.6	6.6	32
	221.5	355.0	576.5	2.10	1,304.0	105.0	44.6	13.8	7.6	6.4	53
	248.6	398.6	647.2	2.30	1,428.8	106.6	46.3	13.8	9.0	8.0	37
	242.7	410.9	676.3	2.27	1,437.8	107.0	46.5	14.2	8.0	7.7	44
	282.6	391.0	673.0	2.68	1,405.2	105.0	44.3	13.9	7.0	8.3	39
	302.4	424.2	626.6	2.88	1,526.0	109.0	44.5	14.0	7.8	9.0	28
	338.2	413.8	752.0	3.10	1,580.5	109.0	46.5	14.4	8.0	9.3	18
	338.7	322.1	660.8	3.10	1,459.7	109.0	47.0	14.0	7.8	9.8	12
	345.5	426.1	771.6	3.44	1,528.3	99.5	40.3	14.5	7.6	8.8	10
	355.8	419.1	775.0	3.67	1,398.8	96.6	37.1	13.5	7.0	11.4	6
	385.8	419.0	800.0	3.90	1,688.0	98.0	42.0	15.0	8.0	11.0	2
	429.0	452.5	881.5	4.10	1,747.0	104.5	44.0	14.6	7.8	9.5	6
over	475.8	268.3	744.1	4.85	1,456.0	98.1	38.3	13.5	6.6	10.1	6

TABLE 16.—*Correlation between height of stalk and number of nodes.*

HEIGHT STALK	NUMBER NODES 11	12	13	14	15	16	17	18	
81-85	1	2	2	2					7
86-90	1	4	5	3	1	1			15
91-95	5	5	13	7	1				31
96-100	8	10	28	25	13	2			81
101-105		4	13	10	14	4		1	46
106-110		3	18	30	9	5			65
111-115		1	9	17	5	6	1		39
116-120		1	6	10	11	2	4		34
121-125			1	7	4	1		1	14
126-130			2	2	1	1	1		7
131-135					1				1
136-140						1			1
	10	30	97	113	60	23	6	2	341

Correlation between height of stalk and height of ear	.640 ± .022
Correlation between height of stalk and number of nodes	.410 ± .080
Correlation between height of stalk and ear node	.354 ± .082
Correlation between height of stalk and length of shank	.146 ± .086
Correlation between height of stalk and leaf area	.382 ± .031
Correlation between height of stalk and weight of ear	.208 ± .085
Correlation between height of stalk and weight of stalk	.299 ± .033
Correlation between height of stalk and total weight	.314 ± .038

Variation constants.

	Mean	Standard deviation	Coefficient of variation
Total weight (gms.)	637 ± 0.50	13.82 ± 0.35	2.08 ± 0.053
Leaf area (sq. in.)	1392 ± 0.82	22.47 ± 0.57	1.614 ± 0.041
Weight of stalk (gms.)	251.3 ± 0.26	7.33 ± 0.18	2.90 ± 0.075
Weight of ear (gms.)	374.1 ± 0.37	10.20 ± 0.26	2.72 ± 0.070
Height of ear (ins.)	44.0 ± 0.27	7.48 ± 0.19	17.00 ± 0.430
Height of stalk (ins.)	104.9 ± 0.36	10.10 ± 0.26	9.62 ± 0.248
Length of ear shank (ins.)	8.0 ± 0.11	3.16 ± 0.08	39.50 ± 1.018
Number of nodes	13.8 ± 0.045	1.25 ± 0.032	9.06 ± 0.233
Ear node	6.7 ± 0.041	1.12 ± 0.028	16.71 ± 0.431

Subject	Relative	Coefficient of correlation
Total weight	Height of stalk	.314 ± .033
	Number of nodes	.378 ± .031
	Ear nodes	.203 ± .035
Weight of stalk	Height of stalk	.299 ± .033
Weight of ear	Leaf area	.386 ± .032
	Total weight	.847 ± .010
	Height of stalk	.208 ± .035
	Weight of stalk	.261 ± .034
	Height of ear	.211 ± .035
	Number of nodes	.248 ± .034
	Ear nodes	.205 ± .035
	Length of shank	.223 ± .035
Leaf area	Total weight	.584 ± .024
	Height of stalk	.382 ± .081
	Weight of stalk	.578 ± .024
	Height of ear	.435 ± .030
	Number of nodes	.622 ± .022
Height of stalk	Height of ear	.640 ± .022
	Number of nodes	.410 ± .030
	Ear nodes	.354 ± .032
	Length of shank	.146 ± .036
	Weight of stalk	.299 ± .033
Height of ear	Number of nodes	.457 ± .029
	Length of shank	—.054 ± .036

CONCLUSIONS.—As stated before, the object of this investigation was largely to find whether there were marked correlations existing in the corn plant between parts of the plant and useful characters; in other words, to find what constitutes a productive type of plant. It is difficult to determine just what constitutes a productive plant. Is it *actual* grain produced or *relative* amount of grain produced? For example, two plants may each produce 500 grams of grain, but in one case the stalk weighs as much as the grain, while in the other it may be only one-half as heavy. *A low relative leaf area seems desirable.*

A long ear shank is associated with a high actual yield of ear (growth correlation as the plants are larger), and a short shank with a high proportion of ear. *Assuming high proportion of corn to be desirable, a short shank is preferable.*

A high ear (above average height) is associated with larger plants and higher *actual* yield, but slightly lower *proportion* of ear and a very little increase in relative leaf area. *Selection of high or low ears does not affect yield.*

A stout, heavy stalk has a larger leaf area; also the ear increases in size up to a certain point, which is about the average in size. A heavy, stout stalk has no advantage in production over one of medium size, tho a medium size is better than a slender stalk in *actual* yield but not in proportion of grain. *Medium in stoutness of stalk would seem best.*

According to the method of study used there is not a high degree of correlation between various parts of the corn plant. If either high *actual* yield or high *relative* yield is regarded as indicating a productive type, then none of the plant characters studied. can be regarded as closely enough correlated with prostore of carbohydrates. This does not seem to be borne out by the data here presented. On the contrary there would seem to be some merit in selecting large plants with a relatively low proportion of leaf area, since this indicates a high degree of efficiency. If it can be shown that water loss is in proportion to leaf area, then a plant exposing 500 square inches unnecessary leaf surface must demand from the soil much larger quantities of water for its support than a plant with less leaf.

TRANSMISSION OF CHARACTERS.

Before selecting plants having certain characters, it is important to first determine the degree to which we may expect these characters to be transmitted. For this purpose a few distinct types were selected from the 1905 crop to be planted in 1906, the principal aim being to select plants having different relative leaf areas. Twelve plants were selected from 342 measured in 1905. All the selected plants had been grown one plant in a place, 3 feet 8 inches apart each way, with the exception of two plants, Nos. 5-299 and 5-318, which were grown two stalks per hill. The plants chosen represented three classes, as follows:

Low Leaf Area: Ratio leaf area to total weight......1.3 to 1.7
Medium Leaf Area: Ratio leaf area to total weight..2.1 to 2.6
High Leaf Area: Ratio leaf to total weight..........3.2 to 3.6

TRANSMISSION OF RELATIVE LEAF AREA

In 1906 about 30 plants were grown from each mother plant. All were planted in adjacent rows. When the plants were fully developed (August 25), 10 of the most typical plants in each row were measured, and later harvested, to be dried and weighed. A summary of results is shown in Table 17. With certain exceptions there was a tendency to transmit the characters. The exceptions indicate that a plant growing even under the favorable conditions provided in 1905 may not develop in a perfectly normal way. In other words, the relationship of leaf to stalk in a large number of cases would not be a fair indication of the *type* of plant which would be produced. For example, compare No. 5-122, a very low leaf plant, and No. 5-299, a plant having relatively two and one-half times as much leaf area per gram of dry weight. Data on these for the two years following show the former to transmit really a more leafy type.

Using the family records of 1906 as a basis for selection in 1907, eight families were chosen. Table 18 is an arrangement of these families according to their 1906 record. There were two to five plats from each family in 1907. The first five families transmitted their character in a satisfactory manner, but there was some irregularity in the last three. A similar relationship held thruout the next two years—1908 and 1909.

It is to be regretted that a large number of families were not carried thru, but the amount of labor required made this impossible. However, from the data secured it is evident that it would not be difficult to isolate strains of corn differing as much as 25 per cent in the ratio of leaf area to dry matter produced.

TRANSMISSION OF SIZE OF PLANT

In 1905 both large and small plants were chosen, but since then we have attempted to select only plants of normal size and having a normal size of ear, the attempt being to secure plants similar in all respects except the ratio of leaf area to dry weight. Table 19 shows that relative size of plant was not transmitted in any degree. All plants selected seemed to be healthy and normal. It is evident, however, that the variation in size was not inherital, but due to some local cause, altho the environment appeared to be uniform. This would indicate that size of plant is so modified by local conditions that potential qualities can not be judged from the individual. The real character of the plant can only be judged by a study of progeny.

DEGREE OF VARIABILITY

The range in variability of individual plants and families originating from a single plant, in proportion of leaf area to total weight, is shown in Table 20.

In all five years, individual plants were found having about three times as much relative leaf as others. While the number of families tested was small, yet the highest family each year had about one-half more relative leaf area than the lowest.

The fluctuation of characters where all plants are from the same mother plant is illustrated by Table 21. The ten plants upon which detailed data are here presented form one of the groups selected, as previously explained, to represent a family. As the ten most typical plants were selected, the range of variation is not as great as if all plants had been taken.

.—*Arrangement of 12 families of corn to show transmission of leaf area, 1905-1909.*

1905 Ratio f area . ins.) to weight rams)	1906 No. of plants analyzed	1906 Ratio leaf area (sq. ins.) to dry weight (grams)	1907 No. of plants analyzed	1907 Ratio leaf area (sq. ins.) to dry weight (grams)	1908 No. of plants analyzed	1908 Ratio leaf area (sq. ins.) to dry wt. (grams)	1909 No. of plants analyzed	1909 Ratio leaf area (sq. ins.) to dry wt. (grams)	Av. results, four yrs., 1906 to 1909
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1.3	10	2.15	30	1.95	60	2.33	60	2.40	2.21
1.4	10	2.91	40	2.50	....	....	....	....	....
1.5	10	2.67	....	....	....	....	....	....	....
1.6	10	2.31	....	....	....	....	....	....	....
1.6	10	2.20	30	2.09	60	2.32	50	2.46	2.27
1.7	10	2.21	30	2.14	....	....	....	....	....
1.51	60	2.41	180	2.17	120	2.32	110	2.43	....
2.1	10	2.82	30	2.66	30	2.75	30	2.94	2.79
2.1	10	2.82	....	....	....	....	....	....	....
2.6	10	2.87	....	....	....	....	....	....	....
2.6	10	2.91	20	2.81	30	2.74	30	2.85	2.81
2.35	40	2.85	50	2.73	60	2.74	60	2.89	....
3.2	10	2.71	20	2.47	30	2.62	30	2.48	2.57
3.6	10	3.12	50	2.45	30	2.47	30	2.92	2.74
3.4	20	2.91	70	2.46	60	2.54	60	2.70	....

18.—*Summary: 8 families arranged according to relative leaf area in 1906 to show transmission of leaf area to following year.*

1905 Ratio leaf area (sq. ins.) to dry weight (grams)	1906 No. of plants analyzed	1906 Ratio leaf area (sq. ins.) to dry weight (grams)	1907 No. of plants analyzed	1907 Ratio leaf area (sq. ins.) to dry weight (grams)	1908 No. of plants analyzed	1908 Ratio leaf area (sq. ins.) to dry wt. (grams)	1909 No. of plants analyzed	1909 Ratio leaf area (sq. ins. to dry wt. (grams)	Average results, four years 1906 to 1909
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1.3	10	2.15	30	1.95	60	2.33	60	2.40	2.21
1.6	10	2.20	30	2.09	60	2.32	50	2.46	2.27
1.7	10	2.21	30	2.14	....	....	....	....	....
1.51	30	2.19	90	2.06	120	2.32	110	2.43	2.24
3.2	10	2.71	20	2.47	30	2.62	30	2.48	2.57
2.1	10	2.82	30	2.56	30	2.75	30	2.94	2.79
2.65	20	2.77	50	2.51	60	2.68	60	2.71	2.68
1.4	10	2.91	40	2.50	....	....	....	....	....
2.6	10	2.91	20	2.81	30	2.74	30	2.85	2.82
3.6	10	3.12	50	2.45	30	2.47	30	2.92	2.74
2.53	30	2.98	110	2.58	60	2.60	60	2.88	2.78

TABLE 19.—*Corn plants arranged according to weight in 1905 to show transmission.*

Record No. 19051	Total weight of plant		Weight of ear		Weight of stalk	
	1905	1906 (Average 10 plants)	1905	1906 (Average 10 plants)	1905	1906 (Average 10 plants)
(1)	(2) *Grams*	(3) *Grams*	(4) *Grams*	(5) *Grams*	(6) *Grams*	(7) *Grams*
5-318	345	439	170	131	175	308
5-299	390	500	200	152	185	348
5- 10	660	518	210	161	450	357
5-132	660	482	350	152	310	330
5- 73	680	580	273	247	405	333
5-113	685	476	383	173	310	303
5-123	800	516	320	177	480	339
5-114	815	582	275	190	540	392
5- 26	910	576	395	202	515	374
5- 6	932	512	390	175	542	337
5-127	935	470	275	165	660	305
5-122	1035	496	350	162	685	334

TABLE 20.—*Variation in plants and families in ratio of leaf area to dry weight, 1905-1907.*

Year	No. of plants	Extreme range of variation in individuals. Ratio of leaf area to total weight	No. of families	Extreme range of variation by families. Ratio of leaf area to total weight
1905.....	342	1.3 to 5.0	....	....
1906.....	120	1.5 to 4.2	12	2.15 to 3.12
1907.....	270	1.57 to 4.0	8	1.95 to 2.81

E 21.—*Ten typical plants from a single mother ear to show average variation in type.*

	Height stalk	Height ear ins.	Number nodes	Ear node	Nodes above ear	Weight leaf	Weight stalk	Weight ear	Total weight	Ratio leaf area to total weight	Leaf area
	(2) *Inches*	(3) *Inches*	(4)	(5)	(6)	(7) *Grams*	(8) *Grams*	(9) *Grams*	(10) *Grams*	(11)	(12) *Sq. in.*
..	110	41	16	9	7	42	180	355	577	2.08	1,203
..	106	37	16	8	8	45	170	345	560	2.27	1,273
..	101	42	15	8	7	51	160	295	506	2.86	1,449
..	112	39	14	6	8	42	185	335	562	2.11	1,186
..	105	41	14	7	7	39	155	295	489	2.29	1,118
..	107	44	15	8	7	37	190	300	527	2.01	1,058
..	106	43	14	9	5	46	140	225	411	3.21	1,319
..	110	36	15	7	8	43	200	250	498	2.48	1,224
..	107	36	15	7	8	40	190	315	545	2.08	1,132
..	102	43	16	9	7	45	160	300	505	2.52	1,273
e.	106	40	15	7.8	7.2	46	173	301	520	2.35	1,223

Conclusion.—While wide variations exist naturally, still wider variations occur as the effect of environment, thus introducing an experimental error probably larger than the real variation. This confirms the conclusion, drawn from a study of the correlation tables, that, taking plants as found under field conditions, no characters are to be found closely enough correlated to indicate ability to yield.

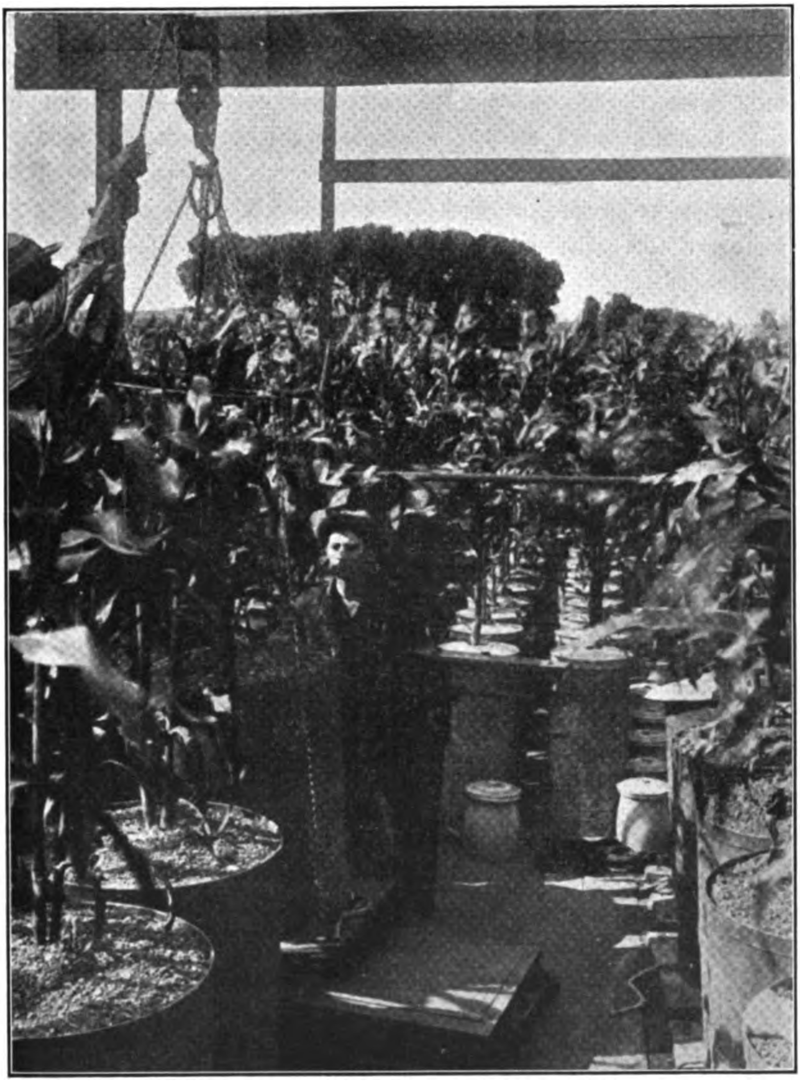
RELATION OF WATER LOSS TO LEAF AREA AND DRY WEIGHT

Since leaf area seems to bear so low a correlation to growth in the plant, it seemed important to determine whether leaf area bore a direct relation to water loss, and also whether the quantity of water used was correlated with growth. To t this a system of potometers was devised and the problem undertaken in 1907.

METHODS USED

The potometers were 36 inches deep by 30 inches in diameter and held 1,000 lbs. of dry soil. They were made from galvanized iron and painted with graphite, inside and outside. At the bottom they were connected to a 4-gallon water jar by a rubber tube. The potometers were buried in the soil so that the top was level with the surface, and arranged in two series with a gangway between, in which the jars were set on a level with the bottom of the potometers. In filling the potometers, 2 inches of coarse gravel was first placed on the bottom to insure an even distribution of the water. A fine mesh screen was laid on the gravel, and the potometer was then filled with 1,000 lbs. of dry soil. The soil was black loam from an alfalfa sod. The corn plants were planted in the center of the potometer, and when 12 inches high, two inches of gravel was placed over the surface, and all covered with a tight lid, except for a hole in the center where the plants grew.

In a check test running all summer there was practically no



Cans used in determining use of water and method of weighing.

loss by evaporation. The plants were watered by placing a weighed quantity in the stone jars as needed.

The object was to grow plants all under uniform conditions as to fertility and quantity of soil, and available water. Tests made several times showed the moisture content to remain almost constantly at 30 per cent, with only about 1 per cent variation between the different potometers. The water loss was estimated by taking moisture samples at the beginning and closing of the experiment and a record of the water added during the season.

The potometers were placed in a cornfield to secure field conditions.

In 1908 no results were obtained, as the plants were injured during early growth.

In 1909 thirty-six smaller potometers were added, making a total number of 48. These new potometers were similar to the old, except that their diameter was 18 inches, and their soil capacity 350 lbs. They were located the same as in 1907, but were not surrounded with soil. This was in order to facilitate lifting them by means of a block and tackle so that the moisture content might be determined by weighing rather than by moisture sampling. Otherwise the treatment was the same.

Two plants are grown in each of the large potometers and one in each small potometer. The growth is normal, the plants averaging about the same size as in the adjacent field. In 1907 10 plants and in 1909 56 plants were tested, while 24 were grown in 1910. Practically the same average results were obtained both years. As a few plants were used from each of several strains we could not hope to isolate plants for the potometers representing extreme variations. On the whole, however, the results are fairly satisfactory. They give at least a suggestion of what might be expected if strains representing greater variations were isolated.

TABLE 22.—*Summary of 1907-'09-'10 results of high leaf and low leaf strains of corn grown in potometers to test relation of water loss to leaf area and to air dry weight.*

Character	1907		1909		1910		Average for '07-'09-'10		
	Low leaf selections (grams or sq. ins.)	High leaf selections (grams or sq. ins.)	Low leaf selections (grams or sq. ins.)	High leaf selections (grams or sq. ins.)	Low leaf selections (grams or sq. ins.)	High leaf selections (grams or sq. ins.)	Low leaf selections	High leaf selections	Ratios of high leaf to low leaf
Weight of ear (gms.).....	275	292	246.5	259.5	242	281	254.5	277.5	1.09
Weight of stalk (gms.)	150	196	150.5	192.1	182	248	160.8	212.0	1.31
Weight of leaves (gms.)....	41	55	36.1	42.7	36	51	37.7	49.5	1.31
Total wt. of plant (gms.)...	466	543	433.1	494.3	460	580	433.0	539.0	1.19
Leaf area per plant (sq. in.)	1,076	1,440	1,011	1,348	965	1,368	1,017	1,385.0	1.36
Ratio: leaf area to dry wt..	2.31	2.65	2.33	2.73	2.10	2.36	2.25	2.57	1.14
Av. water used per plant (kilgms.)................	102.6	131.6	114.1	141.8	108.5	139.4	108.4	137.6	1.27
Av. water used per plant (lbs.)	226	290	251	312	239	307	239.0	303.0	1.27
Grams water to one gram dry weight	220	242	263	287	236	240	239.7	256.3	1.07
Grams water to one gram ear.....................	373	451	463	545	447	496	427.7	497.3	1.16
Grams water to one sq. in. of leaf area.......... ...	95.3	91.4	112.9	105.2	112.4	101.9	106.8	99.5	.93
Depth of water transpired from leaf surface (cm.)...	15.2	14.6	18.1	16.8	18.0	16.3	17.1	15.9	.93

Table 22 is a summary of data for 1907-'09-'10, giving the more important data. From this table it appears that the strains selected for high proportion of leaf were on the whole larger plants, the average weight being 19 per cent heavier. The average leaf area was 36 per cent greater and average water used 27 per cent greater. From these data we conclude that the quantity of water used is about equally modified by the total dry .weight on one hand and relative leaf area on the other. This is also shown by the relative transpiration per square inch leaf area being somewhat greater with the low leaf than with the high leaf types.

If the two types performed in the same manner under field conditions, the results to be expected are shown by Table 23, where it is indicated that it would require about 130 tons more water per acre to produce 50 bushels of corn from the leafy type than the low leaf type.

The difference in relative leafiness is not so great as would be desirable. This is due to the great difficulty in making selections, as every plant selected must be measured and weighed, and of these not all came true to type. The above data were taken under conditions where there was a constant abundant water supply. Under conditions where the water supply was somewhat limited at times, we should expect an increased advantage for that type requiring least for its normal development.

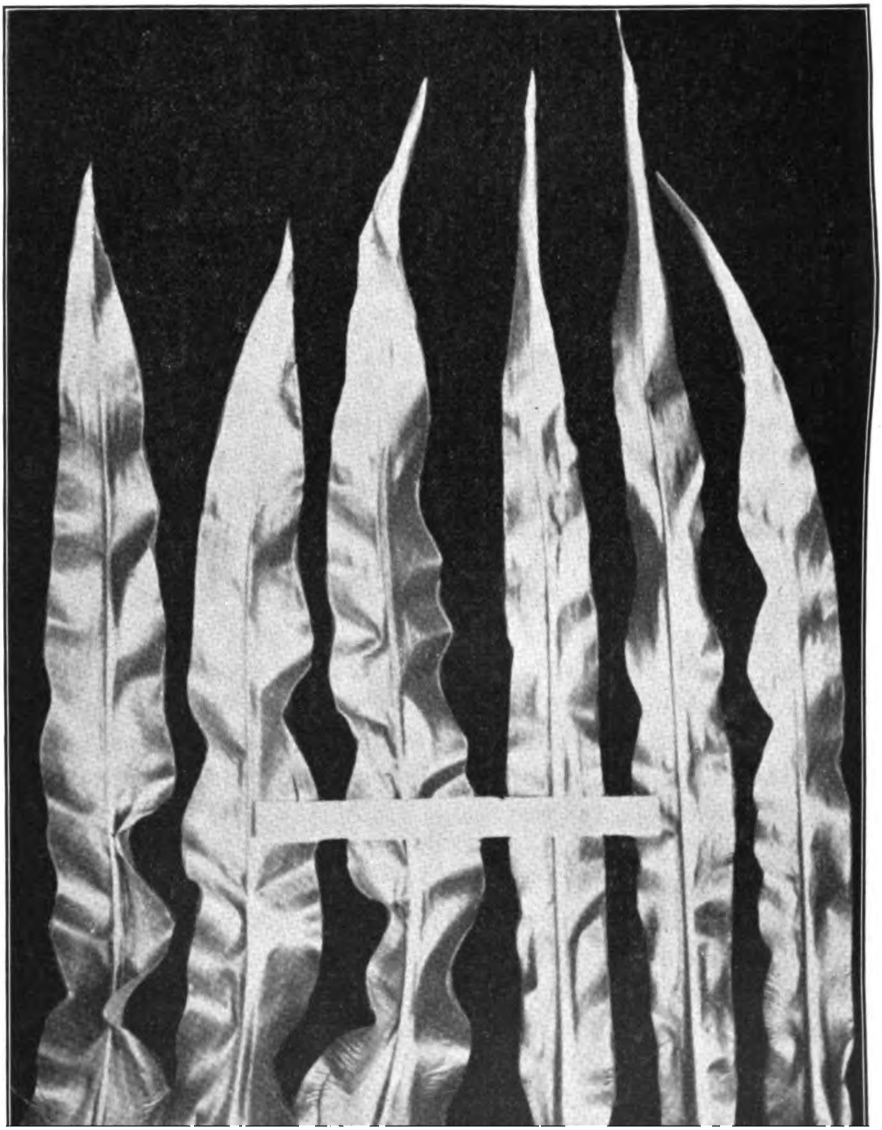
Field plats representing the two strains have been planted for three years. The results are given in Table 24. In both 1908 and 1909 there was some drouth during earing time—this being especially severe in 1909. In 1910, however, there was an excessive rainfall during earing—14 inches of rain falling during the latter half of August. The leafy type also showed a somewhat higher total weight under field conditions, but the increased size was principally in leaf and stem. Under the somewhat dry conditions of 1908 and 1909, the low leaf type had a decided advantage in yield per acre, as the following summary for these two seasons illustrates:

	Low leaf selections	High leaf selections	Low leaf selections	High leaf selections	Low leaf selections	High leaf selections	Low leaf selections	High leaf selections
per acre	6,480	6,480	6,480	6,480	6,480	6,480	6,480	6,480
s of water used per plant	226	290	251	312	239	307	239	303
f water per acre	732	939	813	1,010	774	994	711.6	981
;e weight ear (grams)	275	292	246.5	259.5	242	281	254.5	277.5
.s per acre (6,000 ears)	52	55	46.5	49	45.6	53.0	48.0	52.3
f water to produce 1 bushel	14.0	17.0	17.4	20.6	17.0	18.7	16.1	18.8
f water to produce 50 bushels	700	850	870	1,030	850.0	937.0	806.6	939.0

TABLE 24.—*Field test of high leaf and low leaf strains of corn for yield in 1908 and 1910.*

Character	1908		1909		1910		Av. 1908-'09-'10	
	Low leaf, 1 strain	High leaf, 1 strain	Low leaf, 3 strains	High leaf, 3 strains	Low leaf, 2 strains	High leaf, 2 strains	Low leaf	High leaf
Av. weight of leaves	41.00	61.55	42.40	48.70	43.00	56.00	42.10	55.40
Av weight of stalk	130.40	142.00	141.70	157.90	158.00	183.00	143.30	161.00
Av. weight of ear	249.00	243.00	217.70	220.20	253.00	276.00	240.00	246.40
Total weight of plant	419.00	446.00	401.80	426.80	454.00	516.00	425.00	463.00
Av. leaf area (sq. in.)	857.00	1,204.00	1,127.00	1,395.00	1,073.00	1,369.00	1,019.00	1,323.00
Ratio of leaf area (sq. in.) to total weight (gms.)	2.05	2.70	2.80	3.27	2.36	2.67	2.40	2.88
Yield per acre (bush.)	59.4	50.9	44.9	36.41	50.4	55.8	51.57	47.7

Note.—All the data except yield were taken on 10 selected plants from each *strain;* hence they would not exactly represent the average for the whole plant



Summary for yield and leaf area, 1908-1909.

	High leaf type	Low leaf type	Difference
Leaf area square inches....	1,300	992	308.0, or 31 per cent
Yield per acre, bushels	43.6	52.1	8.5 bu., or 19 per cent

In the season of 1910, with an excessive rainfall, the advantage of yield was with the leafy type, as it has always been in the potometers where the water supply was abundant. This may indicate that in regions having abundant rainfall the leafy type would be desirable, while the low leaf types would be better able to withstand drouth.

CONCLUSION.—In types of corn differing in relative leaf area, the amount of water transpired by the plants is correlated to some extent with leaf area. In a three-year test of two types of corn with an average difference in relative leafiness of 14 per cent, the more leafy type used 7 per cent more water in the production of one gram dry weight under conditions where water was abundant. With the same strains, under field conditions, when water was a limiting factor, the less leafy type had a marked advantage in yield, but in one season with heavy rainfall the advantage was reversed.

SUMMARY

1. While corn plants show a high degree of variability, yet all characters of the plant appear to vary independently of other characters to a high degree (the only exception being the relation of height of ear to stalk). The correlation between actual yield, or relative yield of grain, and other characters is so low that it does not seem that yield could be materially affected by the selection of a corollary.

that it is not possible to judge the inherent characters of the plant in most cases. The inherent characters can only be determined by a study of a representative number of progeny.

3. Corn plants having an average of 14 per cent more relative leaf required 7 per cent more water for the production of an equal dry weight. The leafy plants, tending to produce a higher proportion of stalk, required 16 per cent more water to produce an equal weight of ear.

Where the water supply was abundant, the leafy type gave the highest actual yield, but under limited water supply the less leafy type was most productive.

A COMPARATIVE STUDY OF THE BACTERIAL CONTENT OF SOILS FROM FIELDS OF CORN AND ALFALFA.

By Herbert H. Waite and David H. Squires

The purpose of this investigation was to determine quantitatively and qualitatively the bacterial content of soil taken at levels of one foot from two fields, the one cropped to corn, the other to alfalfa, on the farm of Hon. George Coupland of Elgin, Nebraska.

Each field had been under cultivation for thirty years. The cornfield had never been sown to alfalfa, cereal rotation having been followed out during the entire period. Alfalfa had been grown on the alfalfa field for the last seven of the thirty years. An investigation was made of samples taken on September 13, 1910, at the depth of one foot and of each succeeding foot to the depth of twelve feet.

An exhaustive study of the physiological characteristics of all the different types of bacteria isolated could not be carried out on account of the length of time required for such work. In addition to the distribution of the azotobacter, to which attention is directed in the discussion of results, might also be mentioned the presence in mannite solutions of butyric acid formers in nearly all the samples of soil investigated. The lowest level at which any sample was taken was twelve feet. It would have been of much interest to have continued the investigation, using samples taken at lower levels, especially in the alfalfa field, since the taproots at the depth of twelve feet were still a millimeter or more in diameter.

The importance of determining the bacterial content of the and Störmer,[5] and many others confirmed his results and extended their investigations over many kinds of soils and subsoils. The range of the most intense bacterial activity seemed to lie within the first two meters. In this country, a high bacterial content was found to correspond to a high yield at the Kansas,[6] Delaware,[7] and other Experiment Stations.

The vast numbers of bacteria in the upper layers of the soil were found to check evaporation of the soil moisture by diminishing the speed of the capillary movement of the water. When as many as 100,000,000 per gram[8] are found, the quantity of nitrogen and other plant food locked up in the bacterial bodies must be considerable.

The relation of soil bacteria to soil fertility now became more evident. Further study by Caron,[9] Hiltner and Störmer,[10] and Remy[11] demonstrated that the soil bacteria can be divided into groups according to their physiological functions, as ammonification, nitrification, denitrification and cellulose fermentation.

This differentiation of the soil bacterial flora led to intense study of the various organisms, their environment and their relation to each other and the higher plants. Moreover, as these studies have, as a rule, been carried on in humid regions, where all the important bacterial activities occur within the first five feet,[12] the study of the deeper layers has been generally abandoned. Recent work, however, at the Utah station[13] shows that nitrification in irrigated soils extends to ten feet or more. If this is true of the irrigated soils of the arid West, how much of the productive power of the loess soils may be due to a like cause?

This paper presents the results of investigations on the bacterial content and flora of two loess soils to the depth of 12 feet.

could not be followed for lack of time but enough has been accomplished to show that the bacterial flora of the deeper layers has an important bearing on the productive power of the loess subsoil.

A brief review of the factors governing the bacterial population and flora of soils is necessary to the proper interpretation of results. Nitrification, denitrification, and cellulose fermentation are the principal bacterial processes going on in Nebraska. Except possibly in the southeastern part of the state, the formation of soluble mineral salts thru bacterial action and subsequent loss by leaching is not serious as yet. Alway[14] has shown that the principal mineral elements of plant food are still abundant in the Nebraska loess. That this is a serious problem in more humid regions is shown by the work of Voelcker,[15] Frankland,[16] and recently by Hall and Miller.[17]

Of all the factors controlling nitrification, organic matter is perhaps the most important. This applies more especially to the azotobacters, which are aerobic and thus are dependent on the anaerobes, fungi, and algae for the preliminary decomposition of organic matter to humus, on which they depend for their carbon.[18] Humus, even in large amounts, is favorable to nitrification, as it seems to favor the multiplication of the organisms, according to Müntz.[19]

In some cases, the addition of large amounts of organic matter to a soil has been followed by decreased nitrification or even by denitrification. This result can be explained in various ways. Stranak[20] has observed that under certain conditions A. chroöcoccum reduces nitrates to ammonia in the presence of nitrates and does not fix atmospheric nitrogen. Ampola and de Grazia[21] observed that denitrification takes place comparatively rapidly in fresh manure and the yields were decidedly lower on land where fresh than on land where well-rotted manure was applied. The anaerobic conditions in the fresh manure are analogous to the conditions in a waterlogged soil where denitrification is increased.[22]

Another possible cause of denitrification may be the formation of organic acids in decomposition. The azotobacter are quite sensitive to acids; they thrive in a neutral, or, better, a slightly alkaline medium. Vogel[23] estimates this requirement as 0.01 per cent of lime. The addition of leguminous crops to the soil favors nitrification after a time, as large amounts of potash, phosphorus, and nitrates are made available, but the lasting effect of such treatment is partly due to the checking of denitrification by the formation of free sulphur from the decomposition of the plant protein, as H. Fischer[24] has shown. The sulphur set free in the decomposition of a green crop of mustard turned under has the same effect on the soil,[25] even tho mustard is not a legume. The nitrates liberated in the decomposition of the legumes aid the bacteria in oxidizing such substances as tyrosin, neurine, and choline,[26] which are toxic products of decomposition. Soil temperature has a certain effect on the amount of nitrates formed. King[27] found six times as much nitrogen fixed at 36.8 C. as there was at 1.8 C. Bazarewski,[28] however, states that 25-27 C. appears to be the most favorable temperature for nitrification for soils, or 10 C. lower than in pure cultures on artificial media. He also observes that the optimum temperature is apparently the same for denitrifiers and nitrifiers in mixed cultures.

The amount of soil moisture is also an important factor. Schlösing[29] found that nitrification increases with the moisture content as long as aeration is not checked. This is confirmed by Pouget and Guirand[29] and Warrington. Denitrification occurs in many waterlogged soils.

Aeration promotes nitrification to a very great extent. Deherain[30] found that a soil which had been well stirred contained from ten to forty times as much nitrates as did similar unstirred soil. This is confirmed in a more general way by King and Doryland,[31] who found that deep plowing increased the number of bacteria in both sandy and silt soils and tended to decrease the denitrification.

Denitrification is probably not a very important problem under general farm practice in this state, for the necessary conditions are very seldom fulfilled in the loess soil area at least. The loess soil is characterized by good drainage, a good to a high lime content, and plentiful supplies of potash and phosphoric acid. Voorhees and Lipman[32] in New Jersey, after ten years' experimentation, conclude that "denitrification is not a phenomenon of economic importance, in general farming, and under average field conditions."

The cellulose fermentation occurring in the soil is important, as the organisms concerned in this work furnish sugar for the azotobacters with which to fix notrogen.[33] Lipman in fact advises the inoculation of manure with cellulose ferments and later with azotobacters. In well-aerated soils, or those where the subsoil seldom becomes waterlogged, the gas-producing obligative anaerobes are almost entirely absent. These organisms cause losses in organic matter by the production of methane.

The Nebraska loess, then, is well adapted to nitrification, as it has a good supply of mineral plant food, is well aerated, and by reason of the rainfall does not become waterlogged. The harmful bacterial activities, if not entirely at a standstill, are kept at a minimum. The organic matter and humus content is good down to the third foot.

In deeper levels, conditions are slightly different. In comparison with the Utah soil where nitrification was observed at ten feet, the deeper levels (below three feet) of the loess show by chemical analysis[34, 35] less humus and nitrogen, but slightly more phosphoric acid. The most probable reason for the low humus content of the lower levels is that, until the loess prairies were brought under cultivation, the tough sod caused so much loss of the rainfall by run-off that the average annual rainfall never percolated much below the third foot before being taken up by the grass roots, in the growing season. Percolation, then, thru these levels in the early spring or late fall would not promote nitrification noticeably on account of the low temperature of the water. Cultivation increases the moisture content of the loess during the early part of the growing season. Later the crops extend their roots downward in search of this extra water to as far as seven feet[26] and the subsoil is made too dry for further bacterial action.

Except in wet seasons, favorable conditions of temperature and soil moisture occur only for short periods at the beginning and end of the growing season. In the Utah soils, the large amounts of water used insured a plentiful supply (13 to 15 per cent) at all times and of a temperature more favorable to bacterial action than the snow water of early spring or the cold rains of late fall on the Nebraska soils.

METHOD USED IN THIS INVESTIGATION

The soil samples were kept in tin tubes, plugged with cotton at each end. These were the same tubes that were used in obtaining the sample, so there was no disturbance of the soil until the fractions were weighed out. A sterile knife was used to loosen the soil so that the sample for plating could be taken. The sample was weighed in sterile Petri dishes on a chemical balance to within 0.001 gram. One gram samples were taken. After weighing, the Petri dish was kept covered until ready for dilution and plating.

The soil was carefully transferred to flasks of sterile water, each holding 99 c.c. (the evaporation in the autoclave was ascertained by experiment and compensated). Dilutions of 1-10,000 and 1-100,000 were made from the first flask, which, of course, was itself a dilution of 1-100. Gelatine, plain agar, nonproteid agar, and also plain agar plates to be grown in an atmosphere of hydrogen, were made from each dilution. Before plating, the first flask was shaken for five minutes to insure a homogeneous suspension; according to Lipman[37] this suffices to bring practically all the bacteria into suspension. After shaking, quantities were pipetted into other flasks for the higher dilutions. These were shaken for a few minutes to bring about a uniform distribution of the germs in the solution.

The temperature of the water baths in which the gelatine and agar media were melted was ascertained by thermometers, so no decimation of the bacteria could occur at the moment of plating.

The plates were put away to develop at room temperature and were counted in from four to eight days, depending largely on the development of the colonies.

The media varied from the standard as follows:

Gelatine

Twelve per cent gelatine instead of 10 per cent. to insure solidity at high room temperatures.

Mannite agar or non-proteid agar.

Water	1000.00	c.c.
Sodium chloride	.20	gram
Mannite	20.00	grams
Calcium sulphate	.10	gram
Magnesium sulphate	.20	gram
Di-potassium phosphate	.20	gram
Calcium carbonate	5.00	grams
Agar	15.00	grams

Flask culture medium

Water	1000.00	c.c.
Di-potassium phosphate	.50	gram
Glucose	20.00	grams

The object of the mannite agar and the flask culture media is to provide a solid and a liquid medium, which are slightly al-flasks were filled to depths of 2.5 to 3 cm. with the solution, sterilized in the autoclave and inoculated with sufficient soil to cover the bottom from 1 to 2 mm. They were then put away at room temperature for several months, after which time they were examined and plates made to determine the presence of azotobacters.

DISCUSSION OF RESULTS

In the flask cultures azotobacters were demonstrated by such means as staining characteristic colonies on mannite agar and membrane formation. Azotobacters were shown to be in all levels of the alfalfa field except the 1st, 7th, 10th, and 11th; and in all levels of the cornfield except the 1st, 3d, 4th, and 8th ft., showing a good distribution of azotobacters as to depth.

THE BACTERIAL COUNTS

The corn soil shows a decidedly greater number for the first three feet than the alfalfa soil. This is of course due to the improved aeration induced by cultivation.[38] Below five feet there is comparatively little variation on the proteid media counts. It will be noticed that, while there are fewer nitrifiers in the upper layers of the alfalfa soil than in the corn soil, there is a decided balance in favor of the alfalfa soil in the deeper layers. This may be most easily accounted for by remembering that the large alfalfa tap-roots really have a loosening effect on the deeper layers and also that the decay of the roots would furnish the necessary organic food material for the azotobacters.

The work of Fränkel[39] shows that there may be quite a decided fall in the numbers beginning at about 6½ feet and then a more or less gradual rise again at about the 13th foot and then a final decrease. The curves show in general the last rise to begin in this work at about the 9th foot. No sufficient reason can be given for this phenomenon. There is considerable irregularity in the distribution of the anaerobes (only facultative anaerobes were found) if the number foot by foot is taken, but a mean would show a slight increase to the tenth foot, which is the maximum in both fields.

CONCLUSIONS OF THE CULTURES ISOLATED

The great majority of these are acid formers. Sixteen produce a definite acid reaction and A1122 a decided one. Two are slow acid producers. Seven give an alkaline reaction. While this does not give a true idea as to their relative numbers in the soil, it is certain that the acid formers are abundant and necessarily so, as they have an important role in making available the supplies of mineral phosphates[40] in the soil.

Since plant roots excrete very little acid,[41] contrary to the popular idea, but work by oxidation or by the aid of carbon dioxide, the importance of bacterial acid production becomes more evident. Six reduced litmus and seven peptonized milk casein. Twenty liquefied gelatine.

The oxidizing enzymes produced by bacteria play an important part in the oxygen fixation in soils, especially those rich in organic matter, according to Schreiner and Reed,[42] but the chemistry involved is not well understood. Something of its value is indicated by the fact that some of the organic toxins in the soil that are poisonous to higher plants can be oxidized quite readily as dihydroxystearic acid and agrosterol.[43]

Table 1.—*Bacteria per gram of soil.*

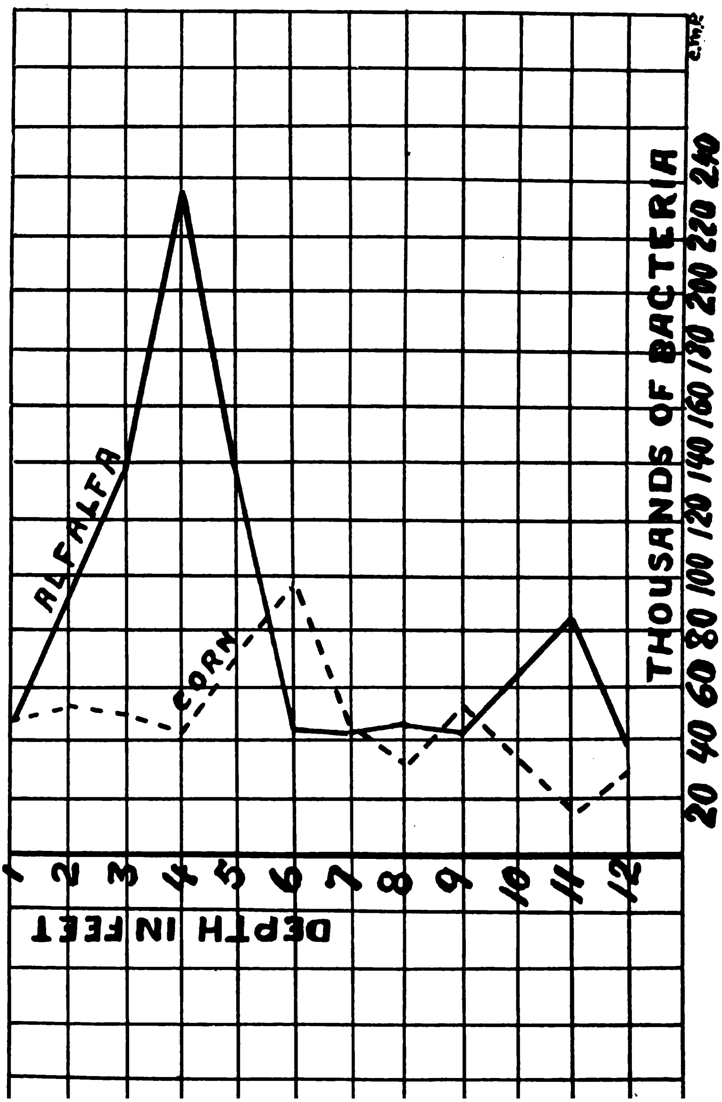
Depth in feet	In gelatine	In plain agar	In non-proteid agar	In plain agar in hydrogen atmosphere
A 1	800	65,850	20,500	12,600
2	90,600	22,000	33,000	73,350
3	136,750	42,550	41,000	3,500
4	237,700	54,300	10,350	6,850
5	139,930	40,750	43,400	37,250
6	44,200	20,100	6,450	8,450
7	42,500	13,750	6,850	9,850
8	46,650	35,050	8,000	71,450
9	41,650	61,100	23,800	41,000
10	63,350	76,500	58,350	86,700
11	86,000	43,100	44,900	10,500
12	37,300	26,350	16,000	3,500
C 1	48,350	2,435,000	78,800	36,700
2	53,000	1,745,000	42,000	27,000
3	50,000	1,514,000	15,350	40,500
4	42,550	60,000	10,350	33,900
5	70,000	82,350	13,350	13,350
6	95,000	44,300	1,700	5,250
7	24,500	59,700	5,150	36,800
8	33,200	63,850	1,300	40,000
9	58,000	39,300	2,450	33,350
10	34,100	65,350	1,500	73,950
11	7,300	21,950	2,400	57,300
12	15,450	65,700	2,250	36,700

TABLE 2.—*Cultural characteristics of different organisms isolated from samples from cornfield.*

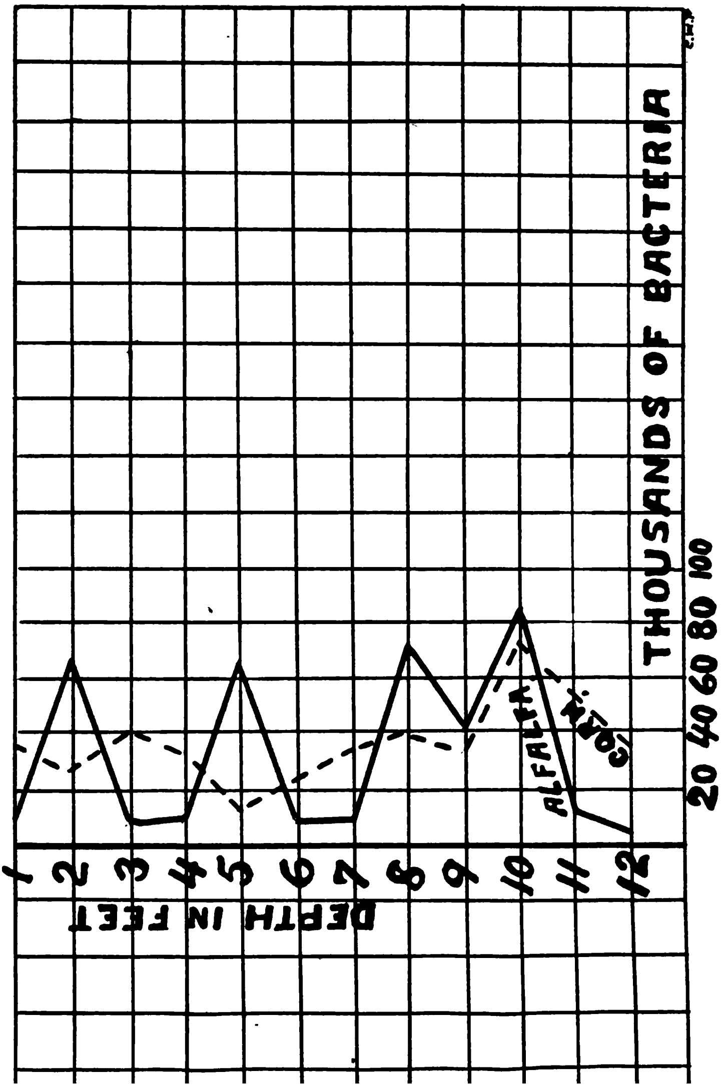
	Designation of organisms	C1	C2	C3	C4	C5	C6	C7	C8
	Slide No.	I	II	III	IV	I	I	I	II
	Depth of sample in feet	2	2	2	2	5	7	12	12
	Diam. over 1 mu	......	......	......	.....	......	......	......	......
	Chains filaments	.....	......	......	....	+	......	+	......
	Endospores	....	....	......	+	+	......	......	......
	Capsules	.....	......	......	......	......	......	+	.....
	Motile	......	+	......	+	.....	.....	.....	......
Broth	Cloudy turbid	+	......	+	+	......	+	+	+
	Ring	+	......	......	.....	.....	......	......	......
	Pellicle	......	......	+	......	......	.....	.....	......
	Sediment	+	... .	......	......	+	......	+	+
Agar	Shining	.. ..	+	+	+	+	+	+	+
	Dull	.....	.....	......	.....	......	......	......	......
	Wrinkled	.....	......	......	......	+	......	......	......
	Chromogenic	+	+	+	+	......	+	+	......
Gel. plate	Round	+	+	+	....	......	+	......	.....
	Proteus-like	......	......	......	+	.....	.. ..	+	......
	Rhizoid	....	......	......	......	.. .	....	......	+
	Filamentous	......	......	....	......	......	......	......	... ..
	Curled	......	......	......	......	....	......	......	......
Gel stab.	Surface growth	......	......	......	......	......	......	.....	......
	Needle growth	......	......	......	......	......	.....	......	......
Potato	Moderate absent	......	+	+	......	......	+	.....	......
	Abundant	++	.....	. ....	+	+	......	+	+
	Discolored	.....	......	......	+	......	......	+	......
	Gel. liq	+	+	+	+	+	+	......	+
Litmus milk	Acid curd	+	.....	+	......	+	......	+	......
	Rennet curd	......	....	......	......	......	......	......	......
	Casein pept.	+	......	......	......	+	......	+	+
	Litmus reduction.	+	.....	slow	.....	+	......	+	slow
	Acid production	+	—	slow	—	+	—	+	slow
	Indol	......	......	......	......	....	......	......	......
	Zooglœa	......	......	......	......	......	......	......	......

TABLE 3.—*Cultural characteristics of different organisms isolated from alfalfa field.*

	Designation of organism..................	A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9	A 10	A 11	A 12	A 13	A 14	A 15	A 16	A 17
	Slide No................	I	II	II	III	IV	II	I	I	I	I	I	II	II	I	I	II	I
	Depth of sample in feet	9	11	3	3	3	2	3	4	4	5	7	8	9	9	11	11	12
	Diam. over 1 mu...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Chains filaments..	+	....	....	....	....	....	....	....	....	....	....	....	+	....	....	....	....
	Endospores	+	+	....	....	....	+	....	....	....	....	....	....	+	....	....	+	....
	Capsules	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Motile	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....
Broth	Cloudy turbid	+	+	+	....	....	+	....	+	....	....	....	+	+	+	+	+	....
	Ring...............	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Pellicle............	+	....	+	....	....	....	+	+	+	....	+	....	....	+	....	....	....
	Sediment..........	+	....	+	....	....	+	....	....	..	.	....	....	+	....	....	+	+
Agar	Shining......... ...	+	+	+	....	+	+	+	....	....	....	+	+	....	+	+	+	....
	Dull	....	....	....	+	....	....	....	+	+	+	....	....	+	....	....	....	+
	Wrinkled..........	+	....	....	+	....	....	....	+	+	....	+	....	+	....	....	....	....
	Chromogenic......	....	....	....	....	....	....	....	....	....	+	..	....	....	+	+	....	....
Gel. plate	Round.............	+	....	....	...	+	....	....	+	....	....	....	....	+	+	+	....	+
	Proteus-like.......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Rhizoid............	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Filamentous.......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Curled.............	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gel. stab.	Surface growth...	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....	....
	Needle growth....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Potato	Moderate absent..	+	....	....	+	+	....	....	....	....	+	....	....	....	+	....	....	+
	Abundant..........	....	+	+	....	....	+	+	+	+	....	+	+	+	....	....	+	....
	Discolored.........	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....
	Gel. Liq.........	+	....	+	....	—	+	+	+	+	....	+	+	+	....	+	+	+
Litmus milk	Acid curd.........	.. .	....	....	....	....	+	....	....	....	....	....	....	....	....	....	....	....
	Rennet curd	....	....	....	....	....	....	+	+	....	....	....	....	....	....	....	....	....
	Casein pept.......	....	....	+	....	....	....	....	....	....	....	....	....	....	+	....	+	....
	Litmus reduction..	....	....	+	....	....	....	....	....	....	....	....	....	....	+	....	+	....



1. Diagram showing numbers of bacteria per gram of soil from various depths under corn and alfalfa. Medium—nutrient gelatine.



2. Diagram showing numbers of bacteria per gram of soil at various depths from corn and alfalfa fields. Medium—plain agar in hydrogen atmosphere.

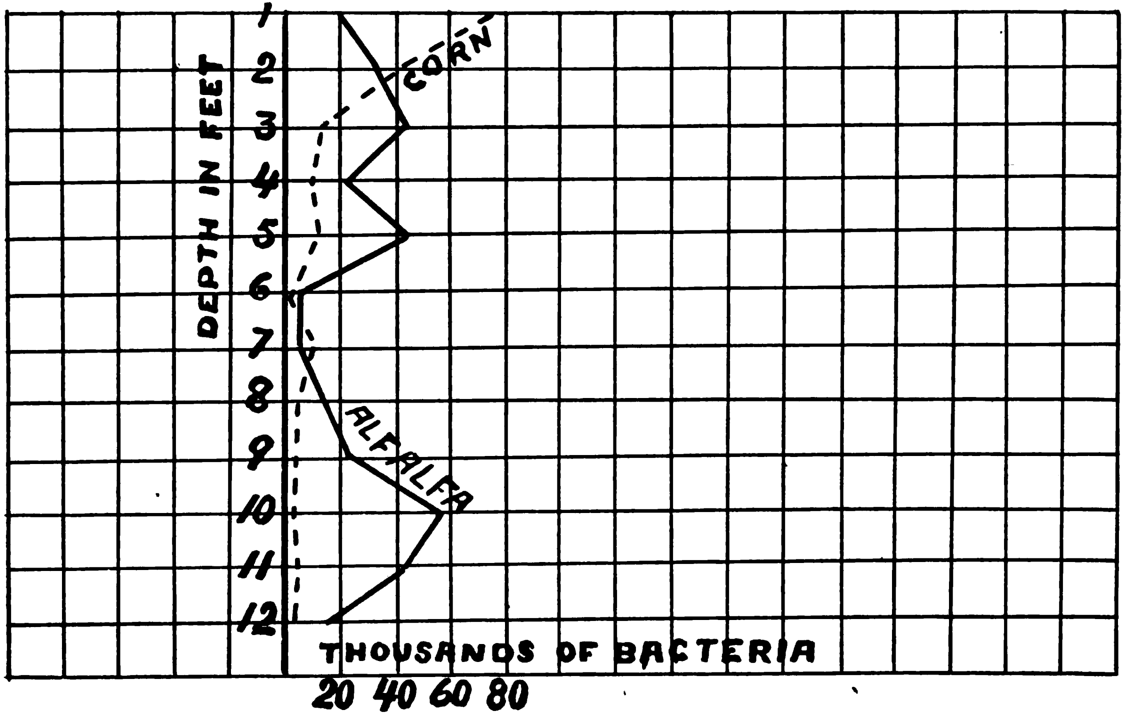


Fig. 3. Diagram showing numbers of bacteria per gram of soil at various depths from corn and alfalfa fields. Medium—non-proteid agar.

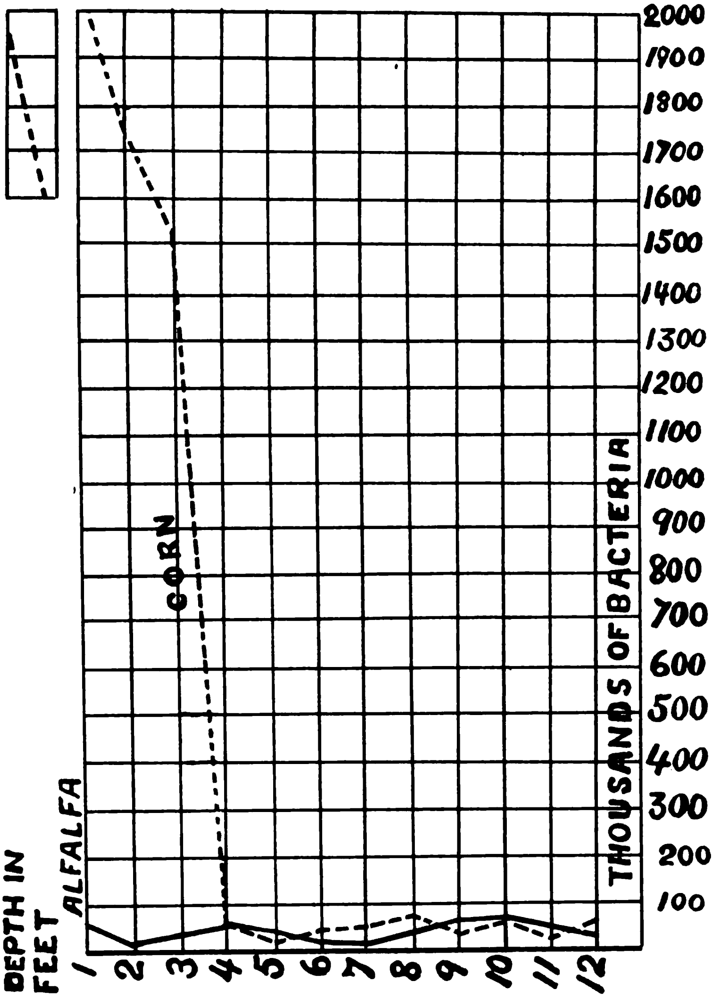


Fig. 4. Diagram showing numbers of bacteria per gram of soil from various depths under corn and alfalfa. Medium—plain agar.

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THE EFFECT OF FOOD ON THE STRENGTH, SIZE, AND COMPOSITION OF THE BONES OF HOGS

By E. A. Burnett

The data given in the following pages were obtained in connection with experiments which formed a continuation of those described in Bulletin 107.

The test of 1908-1909 was carried out with fifty hogs which were fed at the North Platte Substation. There were five lots of hogs, each lot containing ten. The individuals were marked at the beginning of the experiment by metal tags fastened to the ears. At the packing house the tags were accidentally removed from hogs Nos. 1, 3, 9, 10, 13, 17, 19, 20, and 41. As the hogs could not afterwards be positively identified, the data on the bones of these have been omitted from the tables. The experiment began December 12, 1908, when the weights averaged 140 pounds, and closed March 4, 1909.

The feeding experiments of these hogs were in charge of Superintendent W. P. Snyder of the Experimental Substation, North Platte, Nebr. The rations used were as follows:

Lot 1. Ground corn 100 per cent.
Lot 2. Ground corn 90 per cent, alfalfa-meal 10 per cent.
Lot 3. Ground corn 85 per cent, alfalfa-meal 10 per cent, tankage 5 per cent.
Lot 4. Ground corn 85 per cent, alfalfa-meal 10 per cent, bonemeal 5 per cent.
Lot 5, Ground corn 75 per cent, alfalfa-meal 10 per cent, shorts 15 per cent.

The test of 1909-1910 began September 15, 1909, and ended February 5, 1910. This test was conducted at the central Station. At the beginning of the experiment, when the average weight was about 60 pounds, there were five hogs in each of the five lots. On the 20th of November the poorest hog of each lot was taken out, thus reducing the total number to fifteen. In the case of one lot one hog was lost at the packing house, the carcass having been cut up and packed with the company's commercial product before it was noticed that one carcass was missing. The five lots were fed as follows:

Lot 1. Ground corn 100 per cent.
Lot 2. Ground corn 85.5 per cent, alfalfa-meal 10 per cent, bonemeal 4.5 per cent.
Lot 3. Ground corn 90 per cent, alfalfa-meal 10 per cent. During the first month of the experiment, 1.5 per cent of calcium carbonate was added to the ration.
Lot 4. Ground corn 86.6 per cent, alfalfa-meal 10 per cent, crystallized disodium phosphate 3.4 per cent.
Lot 5. Ground corn 85.5 per cent, alfalfa-meal 10 per cent, tankage 4.5 per cent.

In addition, each lot was given 2 ounces of salt daily.

In both tests the hogs were killed by Swift & Co., South Omaha. As in the preceding tests, the carcasses hung for forty-eight hours in the cooler, when they were cut for the market and the humerus, radius and ulna, and femur and tibia of each hog removed, and being properly labeled were shipped to the Experiment Station, where they were cleaned and broken in a testing machine under the supervision of Professor G. R. Chatburn of the Department of Applied Mechanics. (See figs. 1 and 2, pp. 180 and 181. Tables 1 and 9 show the breaking test to which these bones were subjected and give the weight required in breaking each bone.

To break the bones and get their relative strength, an Olsen's Improved Testing Machine with Dial Vernier beam was used. The poise on the beam was operated with a hand wheel so that a perfect balance could be kept. All readings were taken direct. Power for the machine was furnished by an alternating current three-phase motor.

Altho this machine did not break the bones with a blow, such as might be expected when broken in the animal, they were all broken under exactly the same conditions and hence their relative strength could be carefully determined.

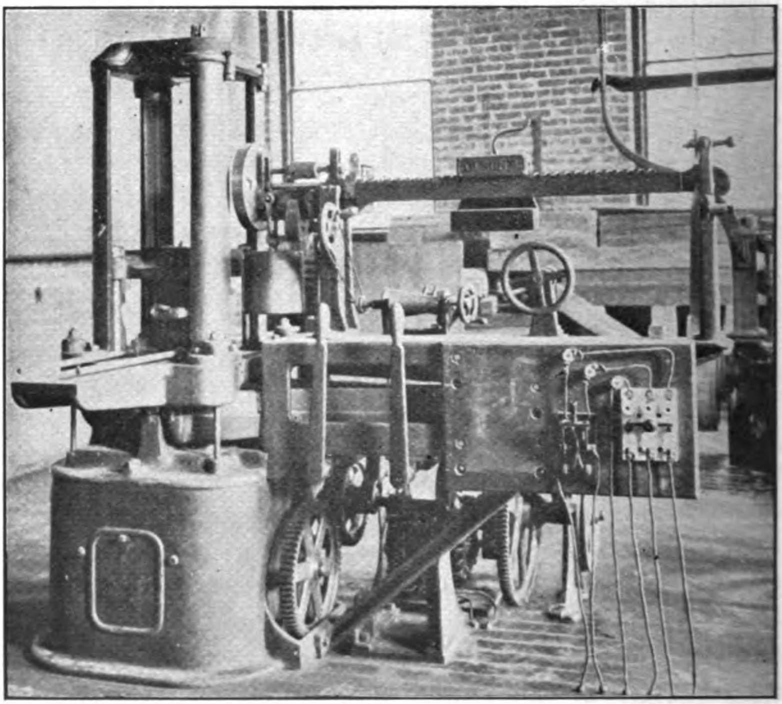


Fig. 1. Olsen's Improved Testing Machine, with which bones in this experiment were broken. (Side view.)

As in the experiments described in Bulletin 107, measure-

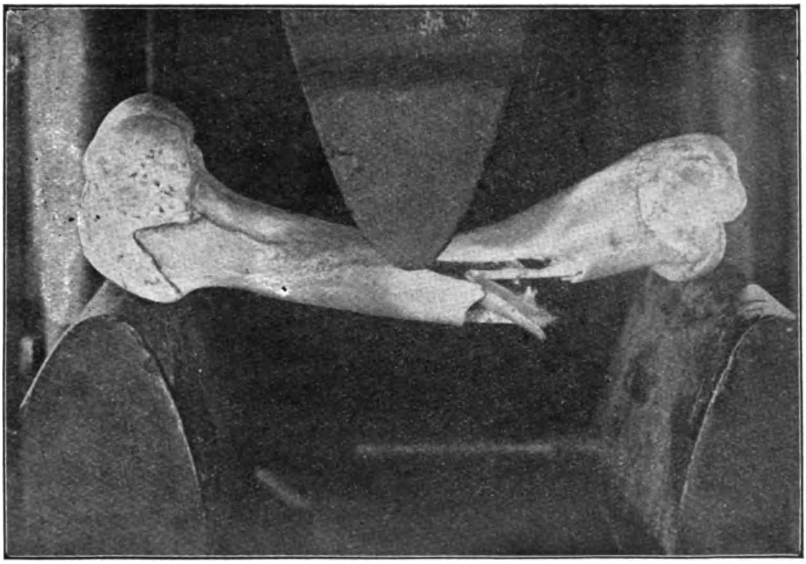
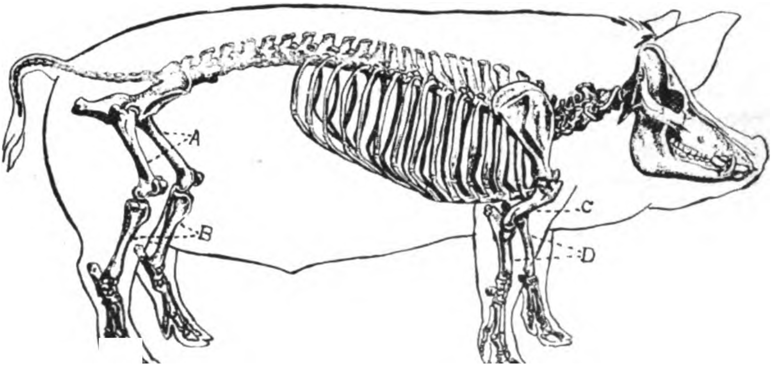


Fig. 2. Showing bone between the anvils of testing machine, after breaking.



tested. The broken bones were used for the determination of the wall thickness and then of the percentage of mineral matter.

In Tables 2 and 10 the extreme length of each bone is given in millimeters (25.4 millimeters = 1 inch).

The circumferences given in Tables 3 and 11 are those of the bones at the most slender portion of the shaft.

The volumes given in Tables 4 and 12 were determined by measuring the water displaced when the bones were submerged in a vessel filled with water.

The specific gravity which expresses the density of the bones (Tables 6 and 14) was obtained by dividing the weight of the bones by the weight of an equal volume of water. One cubic centimeter of water weighs one gram.

The thickness of the bone walls (Tables 7 and 15) was determined by sawing the bone in two parts half way between the ends, removing a portion of the marrow and measuring the wall with calipers. As the wall of a bone does not have the same thickness on all sides, the data given in these tables represent the average thicknesses as closely as they could be estimated. The difficulty of arriving at a reliable numerical expression was so great in the case of the radius and ulna that no data are given in the table of these bones.

In the determination of the percentage of mineral matter in the green bones, the method of procedure was modified somewhat from that described in Bulletin 107. In the case of the five lots in the 1908-1909 experiment, all corresponding bones from each lot were passed thru a green bone cutter and the ground material well mixed. Duplicate determinations of the ash in this were made. Thus there were eight composite samples prepared from each of the five lots, except the fifth. In the case of the right tibiae of this lot, no determination of ash was made, as rats were found to have eaten a hole thru the sack and carried away most of the bones. In the case of the five lots in the 1909-1910 experiment, all the measured bones from each hog were passed thru the green bone cutter and duplicate determinations of the ash made from this ground material.

TABLE 1.—*Breaking strength of bones. Test of 1908-1909.*

Hog No.	Live Wt. *Lbs.*	Femur.		Tibia.		Humerus.		Radius and ulna.		Average of all bones.
		Left.	Right.	Left.	Right.	Left,	Right.	Left.	Right.	
LOT 1. CORN.										
2	164	730	780	575	610	790	735	805	820	730
4	143	735	1130	530	540	760	820	1005	915	804
5	185	800	830	485	510	915	930	990	1050	813
6	165	715	675	500	480	780	750	705	805	676
7	160	740	770	620	600	905	815	960	805	777
8	166	810	715	780	695	850	705	815	870	780
Av.	164	755	816	581	572	833	792	880	877	763
LOT 2. CORN AND ALFALFA-MEAL.										
11	182	800	850	650	650	975	740	820	910	799
12	205	535*	740	480	515	1075	1035	1065	1020	808
14	182	810	750	610	590	910	850	780	1015	789
15	190	630	510	655	635	820	710	820	820	700
16	204	720	625	655	625	970	990	950	970	813
18	212	750	720	765†	670†	1150	950	600†	585†	773
Av.	196	707	699	636	614	983	879	839	886	780
LOT 3. CORN, ALFALFA-MEAL, AND TANKAGE.										
21	178	745	760	665	675	1000	1035	1060	1130	883
22	206	850	870	705	770	1240	940	1135	965	934
23	192	715	900	775	740	1075	1035	1330	1140	963
24	162	650	815	690	635	1060	825	1005	1000	835
25	216	1035	730	900	800	1125	1075	1090	990	968
26	204	830	930	690	720	1440	1190	1345	1225	1046
27	194	780	810	670	680	1080	1075	975	1050	890
28	236	760	900	720	810	1390	1220	1000	1030	978
29	203	970	935	730	760	1110	960	1375	1260	1012
30	143	1010	1075	650	690	1200	1020	1230	1410	1035

TABLE 1.—*Breaking strength of bones. Test of 1908-1909.—Concluded.*

LOT 4. CORN, ALFALFA-MEAL AND BONE-MEAL.

Hog No.	Live Wt. *Lbs.*	Femur.		Tibia.		Humerus.		Radius and ulna.		Average of all bones.
		Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
31	150	1230	1090	695	780	1065	950	1390	1410	1076
32	167	1005	945	640	680	900	955	1200	1135	932
33	183	920	840	775	835	1080	1295	1390	1500	1079
34	204	1065	1000	865	955	1325	1345	990	1030	1072
35	162	730	745	700	685	940	950	1110	1160	877
36	155	640	870	590	735	1090	1060	935	900	852
37	160	1020	965	730	770	1030	1070	1015	1170	971
38	195	945	980	680	730	1090	1170	1115	1215	990
39	192	1160	980	535	655	1220	1185	955	1175	983
40	139	1000	1050	430*	640	965	1030	1210	1535	982
Av.	171	971	946	664	746	1070	1101	1131	1223	981
LOT 5. CORN, ALFALFA-MEAL, AND SHORTS.										
42	182	715	700	555	670	910	865	950	1050	802
43	144	610	655	455	700	770	870	860	875	724
44	164	665	675	570	625	935	850	875	840	754
45	169	700	900	620	625	920	930	1105	1150	869
46	230	830	825	670	610	940	1005	1060	1050	874
47	195	790	1035	605	690	1080	1100	1355	1490	1018
48	196	845	860	725	700	1105	980	990	945	893
49	175	730	790	610	735	915	970	855	740	793
50	116	725	820	500	475	760	665	670	760	672
Av.	175	734	806	590	647	926	915	969	988	822

*Chipped by ax.

Table 2.—*Length of the bones in millimeters. Test of 1908-1909.*

Hog	Femur.		Tibia.		Humerus.		Radius and ulna.	
No.	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.
LOT 1. CORN.								
2	18.0	17.9	16.4	16.2	15.6	15.4	17.0	17.2
4	16.8	16.6	14.9	15.0	13.8	13.9	14.9	14.8
5	17.1	17.0	15.3	15.3	14.8	16.0	15.7	17.3
6	16.8	17.0	15.1	15.6	14.4	14.2	16.0	16.1
7	18.1	17.9	16.1	16.1	14.9	14.8	16.1	15.7
8	17.6	17.9	16.2	16.5	14.9	14.9	17.0	16.8
Av.	17.4	17.4	15.7	15.8	14.7	14.9	16.1	16.3
LOT 2. CORN AND ALFALFA-MEAL.								
11	17.9	18.0	16.0	15.8	15.2	15.3	16.5	16.5
12	16.6	16.7	16.5	17.0	16.3	16.1	17.5	17.8
14	18.0	17.8	16.8	16.6	15.7	15.0	17.8	15.6
15	17.4	17.5	15.7	15.6	14.5	14.7	16.0	16.0
16	18.5	18.5	17.2	16.8	16.0	15.8	17.5	17.5
18	19.4	19.5	16.0	16.3	16.8	16.7	15.0*	15.8
Av.	18.0	18.0	16.4	16.4	15.7	15.6	16.7	16.5
LOT 3. CORN, ALFALFA-MEAL, AND TANKAGE.								
21	16.8	17.0	15.3	15.2	14.2	14.3	16.1	16.1
22	18.5	18.3	16.2	16.3	15.4	15.5	16.9	17.2
23	17.5	17.9	16.2	16.3	15.0	14.8	16.9	16.8
24	18.0	18.0	15.8	15.7	15.1	15.0	16.4	16.8
25	20.2	20.3	17.8	18.0	16.6	16.7	17.8	17.9
26	19.1	18.9	17.5	17.4	16.2	16.2	17.8	17.9
27	19.0	19.0	16.9	17.1	15.8	16.0	17.5	17.6
28	18.7	18.8	17.3	17.2	16.4	16.3	17.6	17.9
29	17.2	17.0	16.3	15.9	15.1	14.8	16.0	16.1
30	17.1	17.0	15.3	15.3	14.2	14.1	15.5	15.8
Av.	18.2	18.2	16.4	16.4	15.4	15.3	16.8	17.0

*Part of end sawn off.

TABLE 2.—*Length of the bones in millimeters. Test of 1908-1909. —Concluded.*

LOT 4. CORN, ALFALFA-MEAL, AND BONE-MEAL.

Hog	Femur.		Tibia.		Humerus.		Radius and ulna.	
No.	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.
31	16.9	16.9	15.8	15.8	14.1	14.2	16.0	16.3
32	17.6	17.7	15.8	15.8	14.1	14.8	15.7	15.8
33	18.8	18.9	17.1	17.0	16.4	15.8	17.9	18.0
34	18.5	18.1	17.3	17.0	14.9	14.8	17.8	17.8
35	19.0	19.1	17.0	17.0	15.7	16.0	17.2	17.4
36	18.8	19.0	17.5	17.0	15.8	16.0	18.0	18.0
37	17.9	18.0	16.7	16.5	15.2	15.1	17.2	17.3
38	18.5	18.4	16.6	16.8	15.8	16.0	17.1	17.2
39	18.9	18.9	17.1	17.1	15.3	15.2	17.3	17.3
40	17.1	17.0	16.2	16.3	14.5	15.0	16.5	16.5
Av.	18.2	18.2	16.7	16.6	15.1	15.2	17.0	17.1

LOT 5. CORN, ALFALFA-MEAL, AND SHORTS.

42	18.0	18.2	16.1	16.2	14.3	14.6	16.7	16.5
43	17.1	17.0	15.3	15.3	14.8	14.6	15.9	15.8
44	17.8	17.9	15.7	15.5	15.8	15.7	16.3	16.5
45	16.4	16.5	14.9	14.8	14.0	13.7	15.0	15.2
46	18.4	18.2	16.5	16.4	15.8	15.7	16.8	17.0
47	17.8	17.6	15.6	15.7	14.4	14.5	16.2	16.4
48	19.0	18.9	17.0	16.9	15.6	15.3	17.3	17.3
49	19.1	19.0	17.4	17.5	16.4	16.2	18.0	17.8
50	15.7	15.6	14.1	14.0	13.2	13.4	14.4	14.3
Av.	17.7	17.6	15.8	15.8	15.0	15.0	16.3	16.3

TABLE 3.—*Circumference of the bones in millimeters. Test of 1908-1909.*

Hog	Femur.		Tibia.		Humerus.		Radius and ulna.	
No.	Left.	Right.	Left.	Right,	Left.	Right.	Left.	Right.
			LOT 1. CORN.					
2	71	70	60	60	68	66	87	89
4	69	66	58	53	66	64	78	76
5	60	62	50	54	64	66	88	88
6	64	64	55	55	60	60	84	82
7	65	64	56	54	64	66	78	77
8	70	70	64	63	70	69	88	89
Av.	66	66	57	56	65	65	84	84
			LOT 2. CORN AND ALFALFA-MEAL.					
11	68	69	58	58	66	64	82	84
12	70	73	62	64	71	72	88	90
14	66	65	60	59	69	63	90	78
15	78	79	64	65	78	78	90	90
16	71	72	64	62	76	70	87	86
18	75	75	70	72	72	74	100	93
Av.	71	72	63	63	72	70	89	87
			LOT 3. CORN, ALFALFA-MEAL, AND TANKAGE.					
21	70	69	61	60	70	70	88	90
22	71	71	65	63	71	71	88	85
23	65	65	58	57	70	71	89	86
24	70	70	65	63	71	70	89	90
25	78	80	64	68	76	77	90	91
26	66	68	59	61	70	72	89	91
27	70	70	63	64	70	69	88	85
28	68	68	60	61	75	73	84	85
29	73	73	60	62	72	70	89	85
30	68	68	60	55	70	69	85	82
Av.	69	70	61	61	71	71	87	87

TABLE 3.—*Circumference of the bones in millimeters. Test of 1908-1909.—Concluded.*

LOT 4. CORN, ALFALFA-MEAL, AND BONE-MEAL.

Hog	Femur.		Tibia.		Humerus.		Radius and ulna.	
No.	Left.	Right.	Left.	Right,	Left.	Right.	Left.	Right.
31	75	75	60	62	72	75	95	92
32	65	67	55	56	65	68	85	82
33	71	72	60	61	74	73	90	91
34	73	72	60	64	70	71	92	90
35	75	74	63	65	79	76	84	89
36	73	75	58	60	75	75	89	90
37	73	74	62	65	69	70	95	93
38	70	70	60	60	72	71	87	87
39	70	68	64	63	68	68	79	78
40	70	69	62	59	72	74	88	88
Av.	71	71	60	61	72	72	88	88

LOT 5. CORN, ALFALFA-MEAL, AND SHORTS.

Hog No.	Femur. Left.	Femur. Right.	Tibia. Left.	Tibia. Right.	Humerus. Left.	Humerus. Right.	Radius and ulna. Left.	Radius and ulna. Right.
42	74	74	61	64	76	75	90	90
43	65	65	55	58	67	64	80	80
44	65	65	55	57	66	65	79	80
45	62	64	58	60	60	66	88	86
46	73	73	60	60	72	74	90	89
47	70	71	60	61	70	70	87	87
48	70	71	62	60	71	70	80	81
49	72	70	60	59	69	70	85	86
50	56	57	49	48	56	55	65	68

Table 4.—*Volume of the bones in cubic centimeters. Test of 1908-1909.*

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.		Total for 8 bones.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
LOT 1. CORN.									
2	140	137	88	82	128	120	90	88	873
4	99	110	58	56	95	87	88	66	659
5	107	105	67	74	97	140	67	99	756
6	109	116	65	75	96	108	72	75	716
7	120	105	74	72	103	105	64	67	710
8	135	135	83	90	126	126	85	90	870
Av.	118	118	72	75	107	114	74	81	764
LOT 2. CORN AND ALFALFA-MEAL.									
11	130	128	102	92	116	114	100	91	873
12	150	152	108	108	144	140	110	115	1027
14	137	134	102	98	138	107	100	67	883
15	138	140	79	85	125	124	86	84	861
16	152	157	86	90	142	128	95	92	942
18	172	170	102	103	150	152	69	69	987
Av.	146	147	96	96	136	129	93	86	929
LOT 3. CORN, ALFALFA-MEAL, AND TANKAGE.									
21	135	130	75	83	108	112	80	80	803
22	140	130	78	76	125	123	82	82	836
23	134	127	79	82	127	122	90	90	851
24	132	122	79	87	118	122	80	83	823
25	178	186	102	106	156	155	110	112	1105
26	160	162	93	100	146	147	100	104	1012
27	140	142	86	88	126	128	90	90	890
28	138	135	87	85	135	138	95	95	908
29	132	126	77	80	123	116	87	80	821
30	122	115	73	69	112	111	75	74	751
Av.	141	137	83	85	127	127	89	89	880

TABLE 4.—*Volume of the bones in cubic centimeters. Test of 1908-1909.—Concluded.*

LOT 4. CORN, ALFALFA-MEAL, AND BONE-MEAL.

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.		Total for 8 bones.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
31	135	137	85	84	124	144	90	95	894
32	118	120	70	71	106	112	80	74	751
33	156	156	98	99	152	150	110	107	1028
34	162	163	96	104	140	142	99	104	1010
35	140	142	85	87	142	142	92	95	925
36	142	152	85	89	140	135	95	96	934
37	157	158	90	95	142	143	114	100	999
38	140	141	85	85	134	133	94	96	908
39	147	143	89	85	126	132	90	95	907
40	123	122	80	82	125	125	87	88	832
Av.	142	143	86	88	133	135	95	95	919

LOT 5. CORN, ALFALFA-MEAL, AND SHORTS.

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.		Total for 8 bones.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
42	140	148	82	85	130	124	93	88	890
43	118	112	75	78	107	104	75	75	744
44	116	116	70	74	112	114	74	74	750
45	112	120	68	72	112	108	77	77	746
46	150	146	95	90	136	137	100	102	956
47	135	138	82	82	116	120	86	90	849
48	140	140	86	88	124	118	86	80	862
49	162	158	100	100	144	143	95	97	999
50	85	85	54	55	74	74	50	48	525
Av.	128	129	79	80	117	116	82	81	813

TABLE 5.—*Weight of the green bones in grams. Test of 1908-1909.*

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.		Total for 8
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	bones.
				LOT 1. CORN.					
2	179.0	171.5	114.5	104.5	156.0	158.5	115.5	115.5	1115.0
4	123.3	122.2	76.0	74.8	124.5	112.5	90.7	78.3	802.2
5	133.0	135.5	81.0	85.0	134.5	182.5	94.7	126.2	972.4
6	134.5	149.0	87.5	99.5	121.7	140.5	98.5	107.0	938.2
7	157.0	143.0	104.0	93.5	134.5	138.5	91.3	89.2	951.0
8	168.7	175.5	112.8	121.7	155.8	158.0	116.5	121.8	1130.8
Av.	149.2	149.3	96.0	96.5	138.0	148.4	101.2	106.3	984.9
				LOT 2. CORN AND ALFALFA-MEAL.					
11	163.5	162.8	104.8	101.5	149.0	146.5	100.5	100.5	1029.1
12	181.5	193.0	119.5	113.4	184.0	176.0	127.5	125.5	1220.4
14	171.0	167.0	111.6	111.5	179.0	139.0	133.7	97.0	1109.8
15	166.5	170.5	102.5	108.5	153.5	152.5	107.2	108.7	1069.9
16	185.0	186.5	116.5	117.3	180.5	159.5	125.5	119.5	1190.3
18	210.5	211.5	127.0	130.0	193.0	194.5	96.3	93.5	1256.3
Av.	180.0	182.0	113.1	113.7	173.1	161.3	115.1	107.4	1146.0
				LOT 3. CORN, ALFALFA-MEAL, AND TANKAGE.					
21	164.0	167.5	103.5	110.5	145.5	151.7	113.0	114.0	1069.7
22	168.0	166.5	107.5	106.5	166.5	162.5	116.7	116.2	1110.4
23	156.1	167.7	105.5	120.0	169.0	156.0	126.3	122.0	1122.6
24	172.5	160.7	110.5	117.0	159.0	166.0	111.5	115.5	1112.7
25	227.5	247.0	140.5	147.9	214.0	218.7	157.0	160.5	1513.1
26	197.5	202.0	133.3	131.0	195.5	200.0	147.0	142.4	1348.7
27	184.5	186.3	116.5	120.6	173.0	172.0	128.0	129.5	1210.4
28	180.0	185.0	120.0	118.5	189.9	192.0	128.7	133.5	1247.6
29	174.5	169.0	110.0	111.0	175.5	160.0	126.5	113.5	1140.0
30	153.0	156.5	101.5	97.2	153.5	153.0	110.5	109.2	1034.4
Av.	177.7	180.8	114.8	118.0	174.1	173.1	126.5	125.6	1190.9

TABLE 5.—*Weight of the green bones in grams. Test of 1908-1909.—Concluded.*

LOT 4. CORN, ALFALFA-MEAL, AND BONE-MEAL.

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.		Total for 8 bones.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
31	175.0	182.5	118.7	117.0	165.4	184.5	126.0	129.0	1198.1
32	161.0	165.0	104.0	103.5	154.5	146.0	113.7	104.7	1052.4
33	200.5	206.0	131.7	136.5	205.5	207.5	150.5	152.5	1390.7
34	209.0	211.5	129.5	138.5	166.0	190.5	136.6	140.8	1322.4
35	183.5	192.0	119.5	121.3	191.0	193.5	128.4	129.5	1258.7
36	168.0	188.4	112.5	119.8	187.0	178.0	131.5	130.5	1215.7
37	209.0	204.5	134.2	135.2	190.0	195.7	144.5	147.0	1360.1
38	193.5	191.0	121.5	122.0	187.1	187.5	135.4	140.7	1278.7
39	201.0	183.0	126.5	121.0	172.5	185.5	127.7	136.6	1253.8
40	161.5	156.5	112.3	110.7	168.0	165.5	120.2	121.7	1116.4
Av.	186.2	188.0	121.0	122.5	178.7	183.4	131.4	133.3	1244.7
LOT 5. CORN, ALFALFA-MEAL, AND SHORTS.									
42	170.0	182.0	103.0	106.1	170.5	156.0	122.5	115.1	1125.2
43	140.5	151.5	92.2	96.5	136.0	130.2	98.5	97.7	943.1
44	144.2	149.2	88.7	93.1	150.0	150.5	99.3	100.2	975.2
45	141.5	154.0	82.5	103.0	146.0	143.5	105.3	102.8	978.6
46	192.5	184.5	127.8	120.0	177.5	179.0	132.5	132.1	1245.9
47	171.2	173.5	106.9	107.6	151.5	156.5	112.5	119.5	1099.2
48	179.5	181.5	113.9	118.9	154.5	162.5	115.1	117.5	1143.4
49	200.5	198.0	114.8	111.5	184.5	187.0	106.2	114.0	1216.5
50	110.0	109.5	72.5	72.8	94.5	95.0	63.5	63.2	681.0
Av.	161.1	164.8	100.2	103.3	151.7	157.1	106.1	107.0	1045.3

TABLE 6.—*Specific gravity of the green bones. Test of 1908-1909.*

LOT 1. CORN.

Hog No.	Femur.		Tibia.		Humerus.		Radius. and ulna.		Average of 8 bones.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
2	1.278	1.252	1.301	1.274	1.219	1.316	1.283	1.313	1.279
4	1.245	1.111	1.310	1.336	1.311	1.293	1.374	1.187	1.271
5	1.243	1.291	1.210	1.149	1.396	1.304	1.413	1.275	1.285
6	1.234	1.284	1.346	1.326	1.268	1.301	1.368	1.426	1.321
7	1.308	1.362	1.405	1.299	1.301	1.319	1.426	1.331	1.344
8	1.249	1.300	1.359	1.352	1.236	1.254	1.369	1.353	1.309
Av.	1.259	1.266	1.322	1.289	1.288	1.298	1.372	1.314	1.301

LOT 2. CORN AND ALFALFA-MEAL.

11	1.257	1.271	1.027	1.103	1.284	1.285	1.005	1.104	1.167
12	1.210	1.269	1.106	1.050	1.277	1.257	1.159	1.091	1.176
14	1.248	1.246	1.094	1.137	1.297	1.299	1.337	1.447	1.263
15	1.206	1.217	1.297	1.276	1.228	1.266	1.246	1.294	1.251
16	1.217	1.188	1.354	1.304	1.271	1.246	1.049	1.299	1.241
18	1.224	1.244	1.245	1.262	1.286	1.279	1.395	1.355	1.286
Av.	1.227	1.239	1.187	1.188	1.274	1.272	1.198	1.265	1.231

LOT 3. CORN, ALFALFA-MEAL, AND TANKAGE.

21	1.215	1.288	1.380	1.331	1.347	1.354	1.412	1.425	1.342
22	1.300	1.280	1.378	1.401	1.332	1.321	1.423	1.417	1.344
23	1.164	1.320	1.335	1.463	1.330	1.278	1.403	1.358	1.331
24	1.307	1.317	1.402	1.344	1.347	1.360	1.393	1.391	1.357
25	1.275	1.328	1.377	1.395	1.371	1.411	1.427	1.433	1.375
26	1.234	1.247	1.430	1.310	1.339	1.360	1.470	1.369	1.345
27	1.317	1.312	1.354	1.370	1.373	1.343	1.422	1.439	1.366
28	1.304	1.370	1.379	1.394	1.406	1.391	1.354	1.438	1.379
29	1.322	1.341	1.428	1.387	1.362	1.379	1.454	1.418	1.386
30	1.254	1.360	1.390	1.408	1.370	1.378	1.473	1.475	1.388
Av.	1.259	1.316	1.385	1.380	1.357	1.357	1.423	1.416	1.361

TABLE 6.—*Specific gravity of the green bones. Test of 1908-1909.*
—Concluded.

LOT 4. CORN, ALFALFA-MEAL, AND BONE-MEAL.

Hog No.	Femur.		Tibia.		Humerus.		Radius. and ulna.		Average of 8 bones.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
31	1.296	1.332	1.396	1.361	1.334	1.287	1.400	1.361	1.346
32	1.366	1.375	1.485	1.457	1.456	1.303	1.421	1.415	1.409
33	1.293	1.320	1.344	1.378	1.352	1.383	1.368	1.425	1.358
34	1.290	1.297	1.349	1.331	1.185	1.341	1.379	1.354	1.316
35	1.311	1.352	1.406	1.394	1.345	1.362	1.395	1.363	1.366
36	1.183	1.239	1.323	1.346	1.335	1.318	1.384	1.359	1.311
37	1.331	1.294	1.491	1.429	1.338	1.368	1.269	1.470	1.374
38	1.382	1.354	1.429	1.435	1.396	1.413	1.440	1.465	1.414
39	1.367	1.279	1.421	1.423	1.369	1.405	1.419	1.438	1.390
40	1.312	1.283	1.400	1.350	1.344	1.324	1.381	1.383	1.347
Av.	1.313	1.312	1.404	1.390	1.345	1.350	1.385	1.403	1.363
LOT 5. CORN, ALFALFA-MEAL, AND SHORTS.									
42	1.214	1.229	1.256	1.248	1.311	1.258	1.317	1.338	1.271
43	1.189	1.352	1.229	1.237	1.271	1.252	1.313	1.302	1.268
44	1.243	1.286	1.267	1.258	1.339	1.320	1.342	1.354	1.310
45	1.263	1.281	1.213	1.430	1.303	1.328	1.367	1.335	1.313
46	1.283	1.264	1.345	1.333	1.305	1.306	1.325	1.295	1.307
47	1.268	1.257	1.303	1.312	1.306	1.304	1.308	1.328	1.296
48	1.282	1.296	1.324	1.351	1.246	1.377	1.338	1.468	1.334
49	1.237	1.282	1.148	1.115	1.281	1.317	1.406	1.149	1.242
50	1.294	1.288	1.342	1.323	1.277	1.283	1.276	1.317	1.300
Av.	1.252	1.281	1.269	1.290	1.293	1.304	1.332	1.321	1.293

TABLE 7.—*Thickness of bone walls in millimeters. Test of 1908-1909.*

LOT 1. CORN.

Hog	Femur.		Tibia.		Humerus.		Average of
No.	Left.	Right.	Left.	Right.	Left.	Right.	6 bones.
2	3.6	4.1	4.5	4.3	6.1	5.4	4.7
4	4.5	4.1	3.7	4.8	...	5.4	4.6
5	5.1	4.8	3.5	3.7	...	5.8	4.8
6	4.1	4.3	3.8	3.5	6.8	4.6	4.5
7	4.5	4.1	4.1	4.3	4.6	5.4	4.5
8	4.8	5.1	4.3	...	...	5.6	4.8
Av.	4.4	4.4	4.0	4.1	5.8	5.4	4.6
LOT 2. CORN AND ALFALFA-MEAL.							
11	4.9	4.6	3.8	...	5.6	5.6	4.7
12	4.9	4.6	...	4.4	6.0	6.5	5.1
14	4.9	5.1	4.0	4.3	6.2	6.0	5.1
15	4.1	4.5	4.0	4.0	5.3	7 5	4.9
16	3.8	3.2	4.0	4.5	5.4	4.8	4.3
18	4.3	4.1	4.6	4.8	...	6.2	5.0
Av.	4.5	4.4	4.1	4.4	5.7	6.1	4.8
LOT 3 CORN, ALFALFA-MEAL, AND TANKAGE.							
21	4.8	3 7	4.6	4.5	5.9	6.2	4.9
22	4.6	4.9	4.6	4.8	5.7	5.7	5.0
23	4.0	4.9	4.9	4.5	6.5	6.2	5.1
24	4.6	4.3	4.3	4.0	6.0	5.6	4.8
25	5.3	5.4	4.8	4.5	5.6	6.0	5.3
26	4.3	5.9	4.6	4.5	7.8	6.5	5.6
27	5.3	5.3	4.9	4.5	6.4	5.6	5.3
28	5.3	6.5	4.8	4.5	4.6	6.5	5.3
29	4.8	4.0	4.1	4.5	6.6	6.4	5.1
30	4.6	4.6	4.6	4.8	6.2	6.2	5.1
Av.	4.8	4.9	4.6	4.5	6.1	6.1	5.1

TABLE 7.—*Thickness of bone walls in millimeters. Test of 1908-1909.—Concluded.*

LOT 4. CORN, ALFALFA-MEAL, AND BONE-MEAL.

Hog No.	Femur.		Tibia.		Humerus.		Average of 6 bones.
	Left.	Right.	Left.	Right.	Left.	Right.	
31	5.3	5.4	...	5.6	6.8	6.7	5.9
32	5.1	4.6	...	4.5	5.7	6.0	5.1
33	4.8	5.9	5.1	5.3	6.2	7.2	5.7
34	5.3	5.3	4.3	4.6	6.2	6.2	5.4
35	3.8	4.1	4.1	4.4	5.9	6.2	4.7
36	3.7	5.4	3.7	4.8	6.0	6.9	5.1
37	4.6	4.8	4.8	4.3	6.2	6.6	5.2
38	5.8	5.6	4.8	4.8	5.7	6.5	5.5
39	6.4	5.6	5.7	5.6	7.3	6.5	6.2
40	5.3	5.6	4.8	4.6	7.0	6.7	5.7
Av.	5.0	5.2	4.7	4.8	6.3	6.6	5.4

LOT 5. CORN, ALFALFA-MEAL, AND SHORTS.

42	4.5	4.5	3.8	5.3	5.9	6.4	5.1
43	3.7	4.8	3.8	4.9	5.1	5.1	4.6
44	3.7	4.5	4.5	4.5	5.3	5.7	4.7
45	4.6	5.3	4.6	...	...	5.1	4.9
46	...	...	3.8	4.1	5.3	4.9	...
47	5.7	4.8	4.5	4.9	...	5.7	5.1
48	3.8	4.1	4.1	4.1	6.0	4.9	4.5
49	3.7	4.0	4.5	4.1	...	5.7	4.4
50	...	4.8	3.8	3.2	5.4	4.8	4.4
Av.	4.2	4.6	4.2	4.4	5.5	5.4	4.7

TABLE 8.—*Percentage of mineral matter in green bones. Test of 1908-1909.*

	Femur.		Tibia.		Humerus.		Radius and ulna.		Average for all bones.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
Lot 1. Corn	35.80	35.95	39.57	40.52	35.82	36.32	40.00	39.10	37.88
Lot 2. Corn and alfalfa-meal.....	36.05	35.02	37.10	36.42	35.75	39.80	40.62	40.42	37.65
Lot 3. Corn, alfalfa-meal, and tankage	38.30	38.00	44.50	40.02	41.10	41.70	43.25	43.72	41.32
Lot 4. Corn, alfalfa-meal, and bone meal	41.77	38.52	41.77	42.82	43.10	43.40	45.60	43.50	42.56
Lot 5. Corn, alfalfa-meal, and shorts	37.71	37.55	39.80	Lost	37.57	41.12	40.82	42.07	39.55*
Average for all.......	37.93	37.00	40.55	39.92*	38.67	40.47	42.06	41.76	39.79

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*In calculating this the percentage of mineral matter in the right tibiae of Lot 5 has been assumed to be the same as in the left tibiae.

TABLE 9.—*Breaking strength of the bones. Test of 1909-1910.*

Hog No.	Live wt. Feb. 4, 1910.	Femur.		Tibia.		Humerus.		Radius and ulna.		Av. of all bones.
		Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
LOT 1. CORN.										
1	153	180	125	340	*	410	385	415	355	...
3	133	275	285	400	530	500	520	345	480	...
4	121	305	190	340	345	485	510	385	430	...
Av.	136	253	200	360	437	465	472	381	422	374
LOT 2. CORN AND BONE-MEAL.										
6	221	*	595	*	640	870	710	1110	1260	...
7	164	...	...	...	...	...	...	...	...	...
8	193	510	720	855	645	745	675	900	1125	...
Av.	193	510	657	855	642	807	692	1005	1192	795
LOT 3. CORN AND LIME.										
9	157	280	290	350	295	415	390	375	380	...
10	159	455	340	500	595	515	470	535	555	...
12	116	340	275	310	415	415	300	390	325	...
Av.	144	358	302	387	435	448	387	433	420	396
LOT 4. CORN AND SODIUM PHOSPHATE.										
13	165	440	275	335	395	615	505	555	510	...
14	144	490	360	510	480	510	530	530	550	...
15	155	350	290	545	525	425	460	520	510	...
Av.	155	427	308	463	466	517	498	535	523	467
LOT 5. CORN AND TANKAGE.										
17	280	645	580	555	610	745	505	910	890	...
18	164	395	370	620	600	655	675	790	880	...
19	286	640	520	545	580	*	715	*	1140	...

Table 10.—*Length of the bones in millimeters. Test of 1909-1910.*

LOT 1. CORN.

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.	
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.
1	172	171	151	152	152	150	166	165
3	178	181	170	170	149	164	175	177
4	173	174	155	157	145	142	159	159
Av.	174	175	159	159	148	152	166	167

LOT 2. CORN AND BONE-MEAL.

6	171	171	154	157	152	153	166	166
7	*	*	*	*	*	*	*	*
8	184	182	164	163	158	157	171	171
Av.	176	175	159	160	155	155	168	168

LOT 3. CORN AND LIME.

9	168	167	149	148	154	152	163	163
10	180	180	165	160	159	158	172	171
12	185	187	172	170	164	165	181	180
Av.	177	178	162	159	159	158	172	171

LOT 4. CORN AND SODIUM PHOSPHATE.

13	176	174	161	163	154	152	169	170
14	189	188	171	171	164	165	179	180
15	178	180	163	165	155	154	172	172
Av.	181	181	165	166	158	157	174	174

LOT 5. CORN AND TANKAGE.

17	188	189	170	172	167	168	180	179
18	180	179	159	159	156	158	165	164
19	185	188	170	170	...	160	...	182
Av.	184	185	166	167	161	164	172	175

TABLE 11.—*Circumference of the bones in millimeters. Test of 1909-1910.*

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.	
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.
LOT 1. CORN.								
1	66	66	58	57	65	65	82	81
3	67	69	56	58	65	65	77	78
4	55	55	40	40	56	55	70	69
Av.	62	63	51	51	62	62	76	76
LOT 2. CORN AND BONE-MEAL.								
6	74	74	68	69	69	69	88	88
7	*	*	*	*	*	*	*	*
8	69	70	64	65	68	68	83	82
Av.	71	72	66	67	69	69	85	85
LOT 3. CORN AND LIME.								
9	65	64	55	54	61	62	80	80
10	71	71	63	62	71	71	88	88
12	69	68	60	60	69	69	79	80
Av.	68	68	59	59	67	67	82	82
LOT 4. CORN AND SODIUM PHOSPHATE.								
13	66	66	58	58	64	64	74	75
14	66	64	59	58	65	64	76	76
15	74	74	60	61	70	70	80	81
Av.	68	68	59	59	66	66	77	77
LOT 5. CORN AND TANKAGE.								
17	70	71	62	62	70	71	78	79
18	61	62	54	55	66	65	83	82
19	69	69	59	60	..	74	..	89
Av.	67	67	58	59	68	70	80	83

TABLE 12.—*Volume of the bones in cubic centimeters. Test of 1909-1910.*

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.		Total.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
				LOT 1. CORN.					
1	116.2	125.0	74.6	74.6*	112.0	112.0	81	76.4	771.8
3	130.0	132.4	77.0	82.3	116.2	130.2	78	83.2	829.3
4	91.8	91.0	59.0	57.1	89.0	87.2	59	56.1	590.2
Av.	112.0	116.0	70.0	71.3	106.0	109.0	72	72.0	730.0
				LOT 2. CORN AND BONE-MEAL.					
6	139	142	79.0	82.0	127	122	90	90	871.0
7	...	...	....	....	...	...	...	..	.....
8	140	137	89.0	90.0	122	112	81	80	851.0
Av.	140	140	84.0	86.0	125	117	86	85	861.0
				LOT 3. CORN AND LIME.					
9	118	120	71.8	71.5	107	110	87	85	770.3
10	127	131	79.0	80.0	126	124	82	82	834.0
12	142	146	92.0	92.0	132	124	89	90	907.0
Av.	129	132	80.0	81.0	122	119	86	86	837.0
				LOT 4. CORN AND SODIUM PHOSPHATE.					
13	119	121	76.0	76.5	112	110	70	70	754.5
14	141	136	84.0	86.0	121	126	81	78	853.0
15	134	134	79.0	81.0	123	121	81	81	834.0
Av.	131	130	80.0	81.0	119	119	77	76	813.0
				LOT 5. CORN AND TANKAGE.					
17	141	142	80.0	86.0	133	130	82	80	874.0
18	103	103	61.0	63.0	98	105	62	68	663.0
19	143	144	86.0	88.0	144*	144	102*	102	953.0

TABLE 13.—*Weight of the green bones in grams. Test of 1909-1910.*

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.		Total.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
LOT 1. CORN.									
1	136.8	130.2	83.2	83.2*	128.2	121.9	91.0	84.0	858.5
3	148.7	150.2	97.7	96.0	130.4	145.1	93.5	97.2	958.8
4	102.5	107.7	67.2	68.2	104.8	102.7	65.4	64.9	683.4
Av.	129.3	129.3	82.7	82.0	121.1	123.2	83.3	82.0	832.9
LOT 2. CORN AND BONE-MEAL.									
6	176.7	180.0	107.5	107.7	169.8	164.2	126.7	123.7	1156.3
7	.....	.....	.....	.....	.....	.....	.....	.....	......
8	180.0	173.0	117.8	116.5	169.1	159.9	107.2	108.5	1132.0
Av.	178.3	176.5	112.6	112.0	169.4	162.0	116.9	116.1	1143.8
LOT 3. CORN AND LIME.									
9	131.2	139.5	85.8	86.2	129.0	129.0	101.8	94.4	896.9
10	151.2	154.5	94.7	94.7	145.5	148.2	99.5	91.8	980.1
12	160.0	164.1	105.8	105.0	155.0	154.0	105.1	101.5	1050.5
Av.	147.5	152.7	95.4	95.3	143.1	143.7	102.1	95.9	975.7
LOT 4. CORN AND SODIUM PHOSPHATE.									
13	145.0	149.3	97.0	99.2	141.2	136.4	90.0	90.0	948.1
14	167.6	162.7	103.5	101.4	146.4	149.4	93.7	94.5	1019.2
15	157.2	155.7	93.7	96.5	148.7	141.7	99.8	98.5	991.8
Av.	156.6	156.0	98.0	99.0	145.4	142.5	94.5	94.3	986.3
LOT 5. CORN AND TANKAGE.									
17	179.7	181.7	104.5	112.8	175.4	170.0	113.5	109.3	1146.9
18	136.7	139.2	78.8	82.0	128.9	139.2	84.6	90.0	879.4

TABLE 14.—*Specific gravity of green bones. Test 1909-1910.*

Hog No.	Femur.		Tibia.		Humerus.		Radius and ulna.		Av. of 8 bones.
	Left.	Right.	Left.	Right.	Left.	Right.	Left.	Right.	
LOT 1. CORN.									
1	1.177	1.042	1.115	1.115*	1.144	1.088	1.123	1.099	1.113
3	1.143	1.126	1.253	1.154	1.122	1.111	1.200	1.167	1.159
4	1.116	1.183	1.139	1.194	1.177	1.177	1.109	1.156	1.156
Av.	1.145	1.117	1.170	1.174	1.148	1.125	1.144	1.140	1.143
LOT 2. CORN AND BONE-MEAL.									
6	1.271	1.269	1.360	1.313	1.337	1.346	1.407	1.374	1.334
7	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	1.285	1.262	1.323	1.294	1.386	1.427	1.323	1.356	1.332
Av.	1.278	1.265	1.341	1.303	1.361	1.386	1.365	1.365	1.333
LOT 3. CORN AND LIME.									
9	1.111	1.162	1.195	1.205	1.205	1.172	1.170	1.110	1.166
10	1.190	1.179	1.199	1.183	1.155	1.195	1.213	1.119	1.179
12	1.127	1.124	1.150	1.141	1.174	1.242	1.181	1.128	1.158
Av.	1.142	1.155	1.180	1.176	1.180	1.203	1.188	1.119	1.167
LOT 4. CORN AND SODIUM PHOSPHATE.									
13	1.218	1.234	1.276	1.296	1.260	1.240	1.286	1.286	1.262
14	1.188	1.196	1.232	1.156	1.209	1.186	1.156	1.224	1.193
15	1.173	1.162	1.186	1.192	1.209	1.171	1.232	1.216	1.193
Av.	1.193	1.197	1.231	1.215	1.226	1.199	1.225	1.242	1.216
LOT 5. CORN AND TANKAGE.									
17	1.274	1.280	1.300	1.311	1.318	1.307	1.384	1.366	1.317
18	1.327	1.351	1.291	1.301	1.355	1.326	1.364	1.324	1.329
19	1.318	1.304	1.319	1.289	1.332*	1.332	1.320*	1.320	1.317
Av.	1.306	1.312	1.303	1.300	1.336	1.322	1.356	1.337	1.320
Av. for 14 hogs	1.208	1.205	1.238	1.225	1.241	1.237	1.248	1.232	1.229

* Estimated.

TABLE 15.—*Thickness of the bone walls in millimeters. Test of 1909-1910.*

Hog	Femur.		Tibia.		Humerus.		Average
No.	Left.	Right.	Left.	Right.	Left.	Right.	of 6 bones.
LOT 1. CORN.							
1	2.5	2.0	2.0	2.0	2.5	2.2	2.4
3	2.5	2.2	2.0	2.5	2.4	2.5	2.3
4	2.0	1.9	1.9	2.0	2.0	2.0	2.0
Av.	2.3	2.0	2.0	2.2	2.3	2.2	2.2
LOT 2. CORN AND BONE-MEAL.							
6	...	4.3	...	4.5	4.5	4.5	...
7	...	...	...	...	...	...	...
8	4.5	3.9	4.2	4.5	4.4	4.0	...
Av.	4.5	4.1	4.2	4.5	4.5	4.2	4.3
LOT 3. CORN AND LIME.							
9	3.0	2.5	2.0	2.0	3.0	3.1	2.6
10	2.5	2.4	2.0	2.5	2.0	2.2	2.3
12	2.5	2.2	2.0	2.0	2.0	2.0	2.1
Av.	2.7	2.4	2.0	2.2	2.3	2.4	2.3
LOT 4. CORN AND SODIUM PHOSPHATE.							
13	2.8	3.0	3.0	2.5	2.8	3.0	2.8
14	3.0	2.6	3.0	2.5	3.0	3.2	2.9
15	2.5	2.7	2.5	2.5	2.6	2.5	2.5
Av.	2.8	2.8	2.8	2.5	2.8	2.9	2.7
LOT 5. CORN AND TANKAGE.							
17	3.0	3.0	3.0	3.5	3.0	3.0	3.1
18	3.0	2.6	3.0	3.0	3.0	3.0	2.9
19	3.2	2.8	3.0	2.4	3.4*	3.4	3.1
Av.	3.1	2.8	3.0	3.0	3.0	3.1	3.0

* Estimated.

TABLE 16.—*Percentage of mineral matter in green bones. Test of 1909-1910.*

	Hog No.	Percentage.
Lot 1. Corn	1	27.05
	3	30.92
	4	32.17
	Average	30.04
Lot 2. Corn and bone-meal	6	44.27
	7	.....
	8	44.03
	Average	44.15
Lot 3. Corn and lime	9	32.12
	10	33.20
	12	30.87
	Average	32.06
Lot 4. Corn and sodium phosphate	13	36.90
	14	36.42
	15	32.02
	Average	35.11
Lot 5. Corn and tankage	17	40.71
	18	40.03
	19	38.93
	Average	39.89

TABLE 17.—*Summary for test of 1908-1909.*

Av. live wt.	Average breaking strength of bones in lbs.	Average breaking strength of bones per 100 lbs. live weight of hog	Average length of bones in mm.	Average circumference of bones in mm.	Average weight of bones in grams	Average volume of bone in c. c.	Average specific gravity of bones	Average wall thickness of bones in mm.	Percentage mineral matter in green bones
LOT 1. CORN.									
164	763	465	16.3	84	985	760	1.301	4.6	37.88
LOT 2. CORN AND ALFALFA-MEAL.									
196	780	397	16.5	87	1146	929	1.231	4.8	37.65
LOT 5. CORN, ALFALFA-MEAL, AND SHORTS.									
175	822	470	16.3	83	1045	813	1.293	4.9	39.79
LOT 3. CORN, ALFALFA-MEAL, AND TANKAGE.									
193	963	499	17.0	87	1131	886	1.361	5.1	41.32
LOT 4. CORN, ALFALFA-MEAL, AND BONE-MEAL.									
171	981	573	17.1	88	1244	919	1.360	5.4	42.56

TABLE 18.—*Summary for test of 1909-1910.*

Av. live wt.	Average breaking strength of bone in lbs.	Average breaking strength of bones per 100 lbs. live weight of hog	Average length of bones in mm.	Average circumference of bones in mm.	Average weight of bones in grams	Average volume of bone in c. c.	Average specific gravity of bones	Average wall thickness of bones in mm.	Percentage mineral matter in green bones
LOT 1. CORN.									
136	371	272	163	63	105.3	91.3	1.143	2.2	30.04
LOT 3. CORN AND LIME.									
144	396	275	168	69	122.0	104.6	1.167	2.3	32.06
LOT 4. CORN AND SODIUM PHOSPHATE.									
155	476	301	169	67	123.3	101.7	1.216	2.7	35.11
LOT 5. CORN AND TANKAGE.									
243	684	276	172	69	136.0	100.4	1.320	3.0	39.89
LOT 2. CORN AND BONE-MEAL.									
207	95	384	165	73	143.0	107.7	1.333	4.3	44.15

The data are summarized in Tables 17 and 18. In both tests the weakest bones were those from the hogs fed corn only. The addition of alfalfa-meal slightly increased the strength. The further addition of shorts gave a noticeable increase, while the addition of tankage and especially of bone-meal gave a very marked increase. This effect of the addition of tankage and bone-meal was the same in both tests and in both the bone-meal gave the strongest bones. The wall thickness and the percentage of mineral matter varied with the breaking strength; the difference between Lots 1 and 2 in the test of 1908-1909 is negligible. Except in the case of the lot fed corn only in 1908-1909, the specific gravity also varied as the breaking strength. The relation of length, circumference, and volume to the breaking strength is not well marked.

The addition for a short time of calcium carbonate in addition to alfalfa to the ration of corn in 1909-1910 shows an appreciable effect, while the constant addition of sodium phosphate together with alfalfa shows a still greater effect, but not as great as that of either the tankage or the bone-meal.

THE UNIVERSITY OF NEBRASKA

TWENTY-FIFTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

NEBRASKA

[illegible]

LINCOLN, NEBRASKA

THE UNIVERSITY OF NEBRASKA

TWENTY-FIFTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF

NEBRASKA

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LETTER OF TRANSMITTAL

THE UNIVERSITY OF NEBRASKA

AGRICULTURAL EXPERIMENT STATION

To His Excellency, Chester H. Aldrich, Governor of Nebraska:

SIR—In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Twenty-fifth Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
Director.

February 1, 1912.

GOVERNOR'S CERTIFICATE

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT,
LINCOLN, February 1, 1912.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR—I hereby acknowledge receipt of the Twenty-fifth Annual Report of the Nebraska Agricultural Experiment Station.

CHESTER H. ALDRICH,

THE OFFICIAL ROSTER OF THE STATION

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(THE REGENTS OF THE UNIVERSITY.)

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[illegible], B. Sc., *Superintendent Experimental Substation,* Mitchell

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TWENTY-FIFTH ANNUAL REPORT

EXPERIMENTAL WORK

The work of the Nebraska Agricultural Experiment Station for the current year has been as follows:

The funds for the Station are secured from three sources, namely: The Adams and the Hatch appropriations are received from the Federal Government in amounts shown by the financial statement of this report. The Experiment Station also uses certain other funds appropriated for general University maintenance and set aside by the Regents at their annual meeting for the maintenance of departments in the College of Agriculture and the Experiment Station. Direct appropriations are also made by the Legislature for certain specific purposes, such as hog cholera investigation and the work of State Entomologist and State Botanist, who are respectively Entomologist and Botanist of the Experiment Station. These appropriations are under control of the Regents of the University and are expended for the purposes authorized by the Legislature.

The State makes direct appropriations also for the maintenance of Substations at North Platte, Valentine, Mitchell, and Culbertson, Nebraska. An appropriation is also made for Farmers' Institute work, which in many ways is identical with extension work of the Experiment Station.

Under the law, the Adams fund must be expended strictly for of Agriculture doing experimental work are available for all necessary purposes of investigation or demonstration, but these funds must largely be used in carrying on routine work which has been planned by the departments. The larger demands upon the departments caused by the growth of the Agricultural College leaves less and less money from State appropriations available for experimental purposes. A fund of not less than $25,000 annually should be appropriated specifically for this purpose at the central plant, as is now done for the branch Experiment Stations located away from the central plant.

Complete plans of work are prepared by each department at the beginning of the calendar year, covering the lines of investigation proposed for the current year. These are submitted to the Station Council for modification or approval. Plans are made for the utilization of all the funds available to the department, so that the work of the Station may progress in a systematic and orderly manner, so as to accomplish the largest results, and practically no funds remain unappropriated for the pursuance of new lines of work. Such lines of work can only be undertaken when the projects now under investigation have been completed. Most lines of work continue for a series of years before final completion. Problems requiring original research are always pressing for investigation, but funds for taking up new lines of work have been so limited that very few new projects have been undertaken in the last three or four years.

It is recognized by the men in the Experiment Station that one of the most important functions of the Station is to carry the results of experimental work to the people. This is done thru bulletins, thru farm demonstrations, and thru other methods of publicity. There is need at the present time of a rather large fund to use for demonstration purposes in cooperation with the farmers of the State. The present appropriation for Farmers' Institute work is not sufficient for that purpose, and was not intended to be used largely for demonstration purposes. Many results of investigation are not adopted by the farmers because they do not have the information or they are not convinced that the methods recommended are adapted to their use. Farm demonstrations are intended to take the results of an experiment into a locality and show the people of the locality exactly how to use them. For example, our experiments have demonstrated that it is profitable for every dairyman to test each cow in his herd and determine the amount of milk and butter produced and the cost of maintenance. Some method should be devised by which cooperative cow testing associations can be organized among dairymen and the efficiency of this method demonstrated to the individual farmer. It is also well understood by those who have studied the development of the live stock industry elsewhere that cooperative breeding among farmers where whole communities shall use the same breeds of live stock tends to a higher efficiency of individual herds and a greater profit to the owners. It is necessary to go into some community and demonstrate these facts before they will generally be adopted by farmers. Methods of testing seed corn have been worked out so that they are fairly efficient. It is necessary at this time to interest individual farmers in breeding and selecting better corn for their own use. The Station could do this if it had funds to assist in the supervision of this work. It has been proved that summer tillage for winter wheat is profitable in average years in western Nebraska. The State and the county should cooperate in demonstrating this fact in a large number of communities so that the practice would be much more generally followed. There are many other lines of demonstration work which could be used to advantage to carry the general knowledge we already have at the Station to the farmer and induce him to put this knowledge into practice. It has been said that the methods of manufacturing butter are twenty-five years in advance of the methods of producing butter on the farm. It has been said that experimental knowledge for the improvement of farm practice is many years in advance of the general adoption of this knowledge by the farmers. If either of these facts be true, the State and the county should combine in some systematic manner to demonstrate these approved methods so that they will be more generally adopted. I quote from the Twenty-fourth Annual Report:

"Not less than $10,000 per year should be used for the purpose of operating farm demonstrations, either upon the county farms or upon private farms in each county of the State. Such cooperation is greatly desired by many farmers, who would gladly bear a portion of the expense, or possibly all of the expense, if they could be guaranteed against actual loss for additional labor involved in carrying on these demonstrations.

"A law should be enacted permitting county commissioners to appropriate money for farm demonstrations in cooperation with the central station, which would furnish seed, expert advice, and assistance to make these demonstrations systematic and effective. This would greatly aid in bringing the best agricultural knowledge in possession of the Experiment Station to those localties in the State where it will be of greatest benefit to the farmers and would demonstrate how to apply new methods in agricultural practice."

LINES OF INVESTIGATION

The lines of investigation carried on under the Adams fund are definitely outlined for the Office of Experiment Stations in the United States Department of Agriculture and are approved by it before investigations in these lines may proceed. At the present time the following lines of investigation are in progress under the various funds:

Plant Diseases.—The principal lines of investigation in progress during the current year are dry rot, stem-end rot, and scab in potatoes. The study of these diseases has been difficult and no remedies can be recommended as yet.

Water Requirements of Corn.—A study of the water requirements of corn has been continued thruout the past season to determine the amount of water required to produce a unit of dry matter under different degrees of soil fertility and different degrees of atmospheric humidity. The amount of water transpired per unit of leaf area was not reduced by increasing the fertility of the soil. The amount of water required per unit of dry weight was greatly reduced by adding manure to an infertile soil, and only slightly by the addition of manure to a fertile soil. The greatest total amount of water was transpired by plants growing in the most fertile soil.

Soil	Total weight of plants	Average leaf-area per plant	Total water transpired per plant	Water transpired per sq. in. leaf area	Water transpired per gram dry weight of plant
	Grams	*Sq. in.*	*Kilograms*	*Grams*	*Grams*
Very infertile soil...	112.75	476	61.961	130.2	549.5
Intermediate fertility	184.39	636	88.306	138.8	478.9
Fertile soil..........	270.69	688	105.840	153.8	391.8
Very infertile + manure............	375.81	980	131.653	134.3	350.3
Intermediate + manure...........	413.63	890	141.079	158.5	341.3
Fertile soil + manure	472.55	993	163.685	164.8	346.6

The amount of water used by plants per unit of dry matter was much greater in a dry greenhouse than in a humid greenhouse where the humidity of the air was kept high by artificial methods. It required in the dry greenhouse 340 pounds of water to produce one pound of dry matter, whereas only 191 pounds of water was required in a humid greenhouse to produce one pound of dry matter. The Twenty-fourth Annual Report, published in 1911, shows that the water loss by the plant is correlated with the water loss from a free water surface, the plant apparently not exercising control in this case. This work will be reported in Bulletin No. 128.

Determination of Experimental Error.—For several years work has been done at this Station to determine the most accurate method of eliminating experimental error in growing crops, and a method of duplicating plats has been devised which tends to reduce the error to a minimum. This method is used in practically all of the experimental plat work at this Station.

SELECTION OF TURKEY RED WHEAT.—The selection of pure strains of Turkey Red wheat was commenced at this Station in 1903 and is still in progress. Several thousand individual mother plants have been grown and from this number three have been selected which were grown last year under farm conditions in commercial quantities. Several other pure-bred strains are still under experiment.

SELECTION OF SEED CORN.—For the past five years two methods of selecting seed corn have been used at this Station which promise good results. In the competitive method of growing seed corn, the seed plat is planted with more than a normal stand of corn, the experiments covering plats where one stalk per hill, two stalks per hill, three stalks per hill, four stalks per hill, and five stalks per hill were planted. The evidence shows that where the seed is selected from thick planting a smaller number of good seed ears are secured, but the average yield per acre from this seed when planted is higher than from seed which has been grown with one or two stalks per hill. This is probably due to the competition which comes from thick planting and which permits only the most vigorous plants to mature good ears.

Good results have also been secured in growing seed corn by the ear-to-row method, where selected ears of corn are planted in individual rows and the progeny from the high-yielding ears is detasseled stalks. This insures perfect cross-fertilization of all the ears used for seed, which increases the yield.

Experiments carried on at this Station indicate that inbreeding of corn is detrimental to the yield and that corn which has been self-pollinated is not valuable for seed.

TYPE OF EARS.—To determine whether there is any relation between the type of ear planted and the yield, 100 ears were planted in an ear-to-row test. Twenty-five ears each, of four distinct types, were selected. Considerable work has been done by way of studying the relation between type of ear planted and yield, and as yet no marked correlation has been found. The following table shows one year's results:

	Yield per acre Bushels
1. Very rough and rather large grained	36.24
2. Large ear—largest type among the ears, but not very rough, and grain of medium depth or less	33.87
3. Long slender ears, rather smooth and shallow in grain	36.13
4. Medium size ears, rather deep grain, deep indentation but not very rough	37.34

EFFECT OF CROP ROTATION UPON YIELD.—Work is in progress to determine the effect of crop rotation and continuous cropping upon the productiveness of Nebraska soils. Our data indicate that a frequent change of crops is necessary to the best production and that all farms in eastern Nebraska should be placed under rotations in which clover or alfalfa forms a part of the rotation. Quoting from the Twenty-fourth Annual Report:

> "There are several reasons advanced for the wonderful effects upon the crop yields of corn grown upon alfalfa or clover land, among which is the increase of nitrogen content of soil, as shown by the dark green color of the succeeding corn crop when growing. This increase in nitrogen content has been noted by several Experiment Stations after careful chemical analyses of the soils before and after the growth of leguminous crops.
>
> "The amount of organic matter added thru the addition to the

soil by the roots, stubble, and fallen leaves has no doubt a very great effect on the increased yield. The past fall the amount of alfalfa roots in the first eight inches was ascertained in an old field and found to be 2.3 tons per acre. When a three-inch stubble was considered in addition to the roots found in the first eight inches the amount of organic matter per acre in this way was increased to 3.2 tons per acre. These results were obtained from rather limited data and not as reliable as the results will be after more investigations along this line.

"Examinations of alfalfa fields made adjacent to the Station Farm, and also in Antelope county, indicate a large accumulation of nitrogen from the roots and the surface growth of clover and alfalfa. One alfalfa field which contained three tons of air-dried organic matter in the first foot of soil showed 125 pounds of nitrogen per acre stored in this organic matter. An alfalfa field one year old showed two tons of air-dry organic matter with 72 pounds of nitrogen. A clover field on the Station Farm in August, following the sowing of the clover in the spring without a nurse crop, showed 2,500 pounds of dry organic matter in the roots with 44 pounds of nitrogen present, and 4,500 pounds of dry organic matter in the tops with 137 pounds of nitrogen present, or a total of 8,000 pounds of organic matter and 181 pounds of nitrogen accumulated during the season of 1910, which had a heavy rainfall in August. This clover field produced a seed crop the same year the seed was sown. An old alfalfa field in Antelope county showed 5,100 pounds of dry organic matter in the first foot of soil with 105 pounds of nitrogen, and 4,100 pounds of dry organic matter in the next 10 feet of soil containing 65 pounds of nitrogen, or a total of 9,200 pounds of organic matter in the alfalfa roots contained in the first 11 feet of soil, carrying a total of 170 pounds of nitrogen."

SOIL INVESTIGATION.—An exhaustive study of the soils of the

The investigation of the alkali soils of the Fremont drainage area has been continued, and a report is in process of preparation.

Seed Potatoes.—In the tests of potato seed tuber production, the following practical points have been determined:

1. The use of home-grown seed in eastern Nebraska from the same stock of tubers year after year results in a decided decrease in total yield and increase in per cent of small unmarketable tubers as compared with the use of northern-grown seed.

2. Seed grown under a litter mulch in eastern Nebraska is equal to the best northern-grown seed.

3. Deterioration of the stock from the use of home-grown seed is gradual and cumulatve, seed grown several years at the Station always being poorer than that grown only one or two years.

4. One year of mulching brings the productiveness of rundown stock of potatoes back to normal conditions. In our test one year's use of the mulch has produced practically as good results as seven years' continuous mulching.

5. Hay, straw, and stable litter are about equally good as a mulch for the production of seed tubers as regards the effect of the next season's crop. On rather poor soil, stable litter usually gives the best immediate yield of seed tubers.

6. To get the full value of the mulch in producing good seed, it must be applied by the time the tubers begin to form.

7. The expense of producing high-grade seed tubers by mulching under farm conditions need not be greater than that of producing the same quality of poorer seed by means of cultivation.

FORESTRY.—Experiments are in progress to determine the most suitable thickness of planting and the most desirable methods of thinning leading hardy trees at the central Station. A study is being made of the desirability of cutting catalpas back to the ground after one or two years' growth, for the purpose of growing fence posts. This practice has been generally recommended by foresters.

The hardiness of varieties and the distance of planting is under observation at the North Platte Station.

Methods of treating fence posts with creosote will be studied to determine the efficiency of such treatment upon cottonwood, box-elder, elm, and other varieties of wood not durable under natural conditions.

INJURIOUS INSECTS.—Experiments are in progress to determine the life history, parasites, and feasible means of control of the pine-tip moth, which has greatly injured the young pines on the forest reserve at Halsey. The investigation is continued.

A study of grasshopper control-measures was in progress during the season of 1911 and will be continued during 1912.

A study of the insect enemies of alfalfa is in progress.

RELATION OF CONFORMATION TO GAINING CAPACITY IN CATTLE.—Forty-eight steers, all born in June, 1910, have been used in a feeding experiment to determine the relative value of different rations in beef production. These steers have also been used to determine the relation of conformation to economy of growth.

The rations were made up to determine the value of silage for summer feeding. Group 1 was fed corn, alfalfa, and corn-stover; Group 2, corn, alfalfa, and corn silage. Enough additional grain was fed with the stover to make up for the corn these groups the grain ration fed was about three-fourths of a full ration. The gains were highest in the alfalfa-fed group that received silage. The second best gain was with corn, linseed-meal, and corn silage; the third best with corn, cottonseed-meal, and corn silage. The gains in the bran-fed group were not only the lowest but much more expensive. Group 6 was fed a full ration of corn, cottonseed-cake, and corn silage. The gains made by these steers were larger than in any group fed on a smaller grain ration, but these gains were made at a higher cost and were less profitable. It was shown in this test that where alfalfa was fed with silage the gains were made on 25 per cent less corn than where corn, cottonseed-cake, and silage was fed without alfalfa.

In each of the six groups were steers of different types, some good and some inferior, upon which individual records were kept to secure data on the correlation of type with gains. Each individual has been measured at intervals to determine the relation between type and gaining capacity, and to determine the tendencies toward change in type with increased fatness and maturity.

HOG CHOLERA SERUM.—An appropriation of $15,000 was made by the last Legislature to establish a plant for the production of hog cholera serum. The plans for the building which is to house this work were delayed in the hands of the architect, but the building is now under construction and will be completed by March or April. In the meantime serum has been produced in a temporary plant and 400,000 cubic centimeters have been furnished to farmers in the State, with quite satisfactory results.

not be able to supply any large part of the serum demanded in times of serious outbreak. The theory of the use of serum to prevent cholera is that it shall be used upon all herds whenever outbreaks occur and in this way entirely stamp out the disease where farmers use the necessary precautions and vaccinate upon the first appearance of the disease. It will probably be many years before all farmers will be educated to the proper use of serum and a sufficient amount be produced to permit its prompt use as soon as an outbreak occurs. Some unfavorable results have occurred where serum has been used. These are due to one of three causes:

First—The presence of cholera in a slow or mild form which does not show upon the animal until after the disease has been present for some days. Under this condition, supposed healthy hogs are frequently vaccinated with serum when in fact they already have cholera in a mild form, as shown when the temperature of the hog is taken. Hogs with abnormal temperatures in cholera herds cannot be protected by serum, even tho they do not show the ordinary physical symptoms.

Second—Hogs which are shipped to eastern Nebraska from other sections where cholera has not been known are more susceptible to outbreaks of cholera than those which have been grown in the cholera districts and which have been produced from parents having greater resistance to the disease, or, in other words, from parents which possess some degree of immunity. The hogs which are shipped from sections where no cholera exists require a larger amount of serum for protection than those grown in cholera-infected regions.

Third—In the "simultaneous method" of treatment, the condition of the virus used with the serum may not always be normal, and this abnormal virus may produce unfavorable results, even when the serum is of proper quality. To insure protection by the simultaneous method, serum should be administered to the hogs without the application of cholera virus. After a period of ten days, serum and virus should be administered simultaneously. Under this method of treatment, mild cases of cholera are produced from which the animal soon recovers, and the immunity is permanent. Some loss is liable to occur under the simultaneous method of treatment, but this loss should not be great, especially under the precautions mentioned above.

A detailed description of the methods of treating hogs with serum is given in Experiment Station bulletins.

COOPERATIVE EXPERIMENTS

The Station is cooperating with a number of farmers in testing the selected strains of Turkey Red wheat developed at this Station. Twenty-one farmers raised these improved strains of wheat in 1910-1911, and twenty-one additional farmers are cooperating in 1911-1912. The average yield per acre secured by the twenty-one farmers last year was a little more than four bushels in excess of the yield from their own seed sown upon the same field. Eight acres of the improved strain in each case was sown as a part of a larger field. The increase in yield was shown mainly upon those fields which produced normal or more than normal yields from local seed. In some instances where all yields were poor, the yield from the selected seed did not equal the yield from the local seed.

The Station is cooperating with a number of farmers in Polk county, known as the Polk County Corn Club, to work out a practical system for the selection of improved seed corn which can be used by any intelligent farmer. At the present time fourteen men in one neighborhood are cooperating. The two methods in use are:

First.—To plant the seed plat with more than a normal stand, about five stalks per hill, detasseling every other row in the seed plat, thus preventing self-fertilization, and select seed only from plants which have developed normal and vigorous ears under this competitive method.

Second.—Seed is grown under the ear-to-row method, in which selected ears of seed are grown in single rows and the yield per acre determined. Only the selected seed from high-yielding ears is used for field planting during the year following.

Either of these methods is simple enough to be used by the farmer who is willing to give a little additional labor to the raising of superior seed corn for his own use.

This Station is in cooperation with the Bureau of Plant Industry in conducting a plant disease survey of the State, reports of which are made from time to time. A handbook of Nebraska plant diseases is in process of preparation.

The North Platte Experiment Station is cooperating with the Bureau of Plant Industry in its Dry Land Agriculture investigations, to determine the methods of tillage and the crop rotations most suitable to the Great Plains area. The Station is also cooperating with the Bureau of Plant Industry in studying the same problems at the Substation at Mitchell, Nebr., this Station being under the direct supervision of the United States Department of Agriculture.

THE NORTH PLATTE SUBSTATION

The North Platte Substation has been in operation since 1904. Its lines of investigation have been described in previous Reports, and nine bulletins upon tillage, crop rotation, varieties, cattle feeding, swine feeding, etc., have been published.

The year 1911 was the most disastrous in the history of the Station. Practically all small grain crops were destroyed by summer drouth and hot winds. The winter wheat raised upon so that the land is in use for two years to produce the average crop above mentioned. Bulletins 114 and 118 specially deal with summer tillage and with crop production at this Station, and are available for distribution.

Since the establishment of the Station, pig feeding experiments have been carried on, using nearly 1,000 pigs to determine the most economical methods for growing pork in the Great Plains area. Bulletin 121, recently published, and 123, in press, give summaries of this work.

The Station has also carried on lines of investigation covering the growing of steers for the feed-lot, and has reported its investigations in Bulletin 117, which is available. We are also conducting at this Station an investigation in the production of baby beef, placing calves at weaning time in the feed-lot and feeding them for market under approved methods with the expectation of marketing them at an age of from fourteen to sixteen months. The present experimental work covers the use of the following rations, namely:

1. Corn, cottonseed-meal, and prairie hay.
2. Corn, alfalfa 80 per cent, prairie hay 20 per cent.
3. Corn, silage, and alfalfa.
4. Corn, silage, and prairie hay.
5. Corn, cottonseed-meal, silage, and prairie hay.

The season just past in western Nebraska should not discourage the farmer who is located in the region named, but it should teach him the necessity of organizing his farm operations so that severe drouth years shall not be fatal to his success. He should, if possible, carry over forage in normal years to be used in years of drouth. He should keep some land in pasture and

THE VALENTINE SUBSTATION

The Substation at Valentine has been established since 1910. Most of this period has been used in establishing a plant and laying out experiments suitable to the sand hill region. The season of 1911 was unfavorable to Valentine as well as to other sections in western Nebraska. While some crops were raised. most crops were destroyed by hot winds and drouth.

Plans are being perfected to establish a dairy herd on the Station farm at Valentine and to work out the problem of growing leguminous crops upon this sandy land along with other crops which can be used for forage.

THE SCOTTS BLUFF SUBSTATION

The Scotts Bluff Substation is operated by the Bureau of Plant Industry of the United States Department of Agriculture. Experiments are being conducted both with dry land farming and with irrigation methods to assist the homesteaders who have located upon lands under the Reclamation Service. The State cooperates in this work by making a small appropriation. The principal lines of investigation cover methods of tillage and rotations most suitable for the region under both dry land and irrigation systems. Special experiments are being conducted with sugar beets, potatoes, etc. This work has been in progress since 1909.

THE CULBERTSON SUBSTATION

The last Legislature made an appropriation to establish a Station at Culbertson, Nebr., under such conditions as the Regents of the University might determine. After several trips of investigation, the Regents, on April 13, 1912, purchased from Mr. W. H. Ferguson the southeast quarter of section 9, township 3, range 31 west, 160 acres of land, for a Demonstration Farm at Culbertson. Only a portion of this land comes into possession of the University at this time, the balance being available when the winter wheat crop is harvested. This land lies one-half mile east of the town of Culbertson, on the north side of the main traveled road. It slopes toward the road, is somewhat rolling, and is all under ditch, so that it may be irrigated. This is a private ditch, so that no water right was acquired with the land.

THE STATION STAFF

Within the past year the following changes in the Station staff have taken place:

Professor A. L. Haecker, for 15 years in charge of the Dairy Department, resigned to take up commercial work. September 1, 1896, he was made Instructor in Dairying and Assistant in Agriculture, and on July 1, 1901, was given full charge of the Department of Dairy Husbandry. He is succeeded by Professor James H. Frandsen, who on October 1, 1911, took charge of this Department, coming to the State from the University of Idaho, at Moscow.

Professor E. G. Montgomery, for four years in charge of Experimental Agronomy, resigned January 1, 1912, to accept a position in the College of Agriculture of Cornell University. His successor has not been appointed.

Professor H. R. Smith, for eleven years Professor of Animal Husbandry, resigned February 1, 1912, to accept a similar position in the College of Agriculture of the University of Minnesota. His successor has not been appointed.

Professor Frank J. Phillips, in charge of the Forestry work, died February 13, 1911.

Professor C. W. Pugsley, in charge of Soil Agronomy, was transferred to the Department of Agricultural Extension as Superintendent of Agricultural Extension and Farm Management. He remains in charge of Farm Management investigations.

Miss Venus W. Pool resigned November 1, 1911, to accept a position in the Bureau of Plant Industry, United States Department of Agriculture.

IMPROVEMENTS

Since the last Annual Report, a laboratory has been erected for the production of hog cholera serum, at a cost of $5,000. This building is constructed of hollow tile covered with cement stucco.

The Horticultural laboratory has been moved from its original site to make place for a natural science building which is to house the departments of Agricultural Botany, Horticulture, and Entomology. This building is to be fireproof and is to cost $85,000. The contract has been let, but construction on the building has not yet commenced.

At the North Platte Station a dwelling-house, to be used for housing and boarding farm help, is under construction. This house is built of hollow tile covered with cement stucco. It will cost $8,000. A sewer system is also in process of construction.

At the Valentine Substation a dairy barn is under construction as an annex to the present horse barn. This building will be constructed of cement block, in harmony with other buildings at the Valentine Substation, and will cost $3,000.

PUBLICATIONS

Regular bulletins giving the results of investigation in the Experiment Station are published in editions of from 20,000 to 40,000 each. Technical bulletins are published in limited editions and are sent out only to scientific men working in the same field and to others upon application. There is at the present time a regular mailing list within the State of 17,000 names. These are continually being added to, and it is desired that all farmers who are interested in the publications of the Station should ask to be placed on the mailing list. The Station is attempting to classify its mailing list under the general subjects of soil fertility and crop production, animal diseases, feeding animals, plant diseases and insect pests, and orchard management. A general mailing list will be continued for those who desire all bulletins, but the expense of publication has become so large that we feel the necessity of sending bulletins only to those who are sufficiently interested in the subject to give the bulletin careful consideration.

The publications of the Station since those named in the last Annual Report are as follows:

Twenty-fourth Annual Report. Presented to the Governor February 1, 1911. 5,000 copies.

Bulletin No. 119 (Volume XXIII, Article IV). Spraying as an Essential Part of Profitable Apple Orcharding. By R. A. Emerson, R. F. Howard, and V. V. Westgate. Distributed March 15, 1911. 25,000 copies.

Bulletin No. 120 (Volume XXIII, Article V) (Extension Bulletin No. 1). Alfalfa Management. By C. W. Pugsley. Distributed May 12, 1911. 40,000 copies.

Bulletin No. 121 (Volume XXIII, Article VI) (Substation Bulletin No. 8). Growing Hogs in Nebraska. By W. P. Snyder. Distributed June 30, 1911. 32,000 copies.

Bulletin No. 122 (Volume XXIII, Article VII) (Extension Bulletin No. 2). Cost of Growing Crops in Nebraska. By C. W. Pugsley. Distributed June 30, 1911. 32,000 copies.

Bulletin No. 123 (Volume XXIV, Article I) (Substation Bulletin No. 9). Fattening Hogs in Nebraska. By W. P. Snyder. (In press.) 30,000 copies.

Bulletin No. 124 (Volume XXIV, Article II) (Substation Bulletin No. 10). Fattening Hogs in Nebraska. By W. P. Snyder. (In press.) 5,000 copies. (Technical bulletin.)

Bulletin No. 125 (Volume XXIV, Article III). Wheat Breeding Experiments. By E. G. Montgomery. (In press.) 30,000 copies.

Bulletin No. 126 (Volume XXIV, Article IV). Native Seed Corn. By E. G. Montgomery. (In press.) 30,000 copies.

Press Bulletin No. 34. How to Combat the Melon Aphis. By M. H. Swenk. Distributed June 26, 1911. 21,000 copies.

Press Bulletin No. 35. Catch Crops for Hay and Pasture. By E. G. Montgomery. Distributed July, 1911. 2,500 copies.

Press Bulletin No. 36. The Distribution and Use of Hog Cholera Serum. By J. H. Gain. Distributed September 26, 1911. 35,000 copies.

AGRICULTURAL EXTENSION

The department of Agricultural Extension has taken over the work formerly done by the department of Farmers' Institutes. Several members of the Experiment Station staff have assisted in institutes during the current year. About 125 institutes were held during the year 1910-1911 previous to April 1. Between October 1 and December 31, 1911, 90 institutes were held, and between January 1, 1912, and October 1, 1912, it is expected about 200 points will be reached, 400 days being devoted to institutes at these institute points.

In addition to regular institutes, nine junior short courses and probably five senior short courses or institute schools covering a period of one week each will be held at different points in the State.

A number of seed-corn trains will be operated by the railroads, covering nearly all the territory on the leading railroad lines of the State. The speakers upon these trains will be in charge of the Agricultural Extension Department of the University. The expense of operating these trains, other than the speakers, will be borne by the railroads or the grain exchanges of the State.

The Extension Department of the University is offering two correspondence courses in agriculture for farmers, teachers, county superintendents, and others.

The appropriation for extension work is $17,500 per year.

Many lines of extension work not yet undertaken should be developed in Nebraska. These should be in the direction of farm demonstrations which will assist the farmers in adopting new

An agricultural survey should be made to determine the relative cost of producing beef and pork upon farms where alfalfa is used as a part of the ration in comparison with other rations; also where silage is used as a part of the ration in comparison with rations where no silage is used. When these data are gathered, they should be given publicity so that other farmers may know the results which are actually being obtained upon farms at the present time.

Similar lines of work should be carried on to determine the production of individual cows in dairy herds and the net profit per cow. This will encourage the keeping of individual records by farmers and will increase the average production and profit from dairying.

An agricultural survey should be made covering the different systems of farming in some typical region of the State, showing the value of the land, the labor expended on the same, the capital invested in live stock and machinery, and the profits if any upon the investment, with the view of classifying these different farms into groups, to determine what method of farming gives the largest return for the capital and labor invested in the business.

Demonstrations should be conducted in southeastern Nebraska covering the management of commercial orchards, to determine what method will give the largest practical results. The results of the application of scientific methods to orcharding will very greatly stimulate the growth of orchards in eastern Nebraska. especially along the Missouri river bluffs, which furnish natural opportunities for orcharding probably equal to any region in the United States.

The effect of summer tilling on the production of winter wheat should be demonstrated upon many farms in western Nebraska to determine the practicability of using summer tillage methods on the average farm.

The men who are engaged in these lines of agricultural survey will soon become competent and practical advisers of the farmers who need assistance in these various lines.

The Extension School, or the Farmers' Short Course, should be extended to many farming regions of the State. A school of one week or two weeks should be held for the discussion of agricultural subjects with practical farmers and the sons of these farmers who cannot attend other agricultural schools will be of enormous value in carrying practical agricultural methods to the people.

Agricultural short courses are conducted for both men and women, separate sections being organized for women, who discuss subjects relating to the improvement of the home.

The appropriation for extension work along the lines mentioned should be very greatly increased, as the appropriation now available is only sufficient for carrying on the Farmers' Institutes and the few Extension Schools mentioned in the above report.

ORGANIZED AGRICULTURE

The meetings of Organized Agriculture have been well attended and are a source of great interest and profit to those in attendance. Several of these associations are now incorporated and receive small appropriations from the State to assist in publishing their annual reports. These meetings bring together many of the leading farmers of the State for discussions which are of large economic value, and should be attended by all progressive farmers.

THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA

FINANCIAL STATEMENT

HATCH FUND

RECEIPTS.

Received by the University (state) treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1911, under the act of Congress approved March 2, 1887 (Hatch fund)	$15,000 00

EXPENDITURES.

Salaries	$8,899 87
Labor	1,471 97
Publications	2,131 11
Postage and stationery	496 61
Freight and express	64 99
Chemicals and laboratory supplies	14 88
Seeds, plants, and sundry supplies	219 66
Feeding stuffs	609 01
Tools, machinery, and appliances	120 15
Furniture and fixtures	131 40
Scientific apparatus and specimens	2 06
Live stock	547 98
Traveling expenses	123 52
Contingent expenses	25 00

FINANCIAL STATEMENT—Continued

ADAMS FUND

RECEIPTS.

Received by the University (state) treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1911, under the act of Congress approved March 16, 1906 (Adams fund)	$15,000 00	

EXPENDITURES.

Salaries		$8,502 50
Labor		2,576 62
Postage and stationery		46 37
Freight and express		88 52
Chemicals and laboratory supplies		160 70
Seeds, plants, and sundry supplies		591 09
Feeding stuffs		761 87
Tools, machinery, and appliances		180 96
Furniture and fixtures		318 75
Scientific apparatus and specimens		758 61
Live stock		312 63
Traveling expenses		701 38
	$15,000 00	15,000 00

FINANCIAL STATEMENT—Continued

SUPPLEMENTAL FUNDS

RECEIPTS.

Moneys received by the University (state) treasurer from other sources than the United States, for the use and benefit of the experiment station and substations for the year ended July 31, 1911:

Balance, July 31, 1910	$8,688 20	
Sales of stock, produce, etc., for year ended July 31, 1911	35,808 33	

EXPENDITURES.

Salaries		$6,982 72
Labor		4,894 40
Publications		32 98
Postage and stationery		613 98
Freight and express		493 98
Chemicals and laboratory supplies		29 02
Seeds, plants, and sundry supplies		5,131 11
Feeding stuffs		12,184 02
Tools, machinery, and appliances		1,317 51
Furniture and fixtures		250 00
Scientific apparatus and specimens		305 16
Live stock		4,836 09
Traveling expenses		785 42
Buildings and land		2,501 00
Balance, July 31, 1911		4,139 14
	$44,496 53	44,496 53

FINANCIAL STATEMENT—Concluded

STATE PROJECTS

Farmers' Institutes—		
Balance, July 30, 1910	$7,131 04	
State General Fund appropriations, two years ending March 31, 1913	35,000 00	
Expenditures, one year to July 31, 1911		$7,698 39
Appropriation balances, July 31, 1911		34,432 65
	$42,131 04	42,131 04

Experimental Substations—			
Balances, July 30, 1910:			
North Platte		$5 07	
Scottsbluff		3,614 02	
Valentine		10,943 93	$14,563 02
State General Fund appropriations two years to March 31, 1913—			
Culbertson		15,000 00	
North Platte		30,000 00	
Scottsbluff		5,000 00	
Valentine		15,000 00	65,000 00
			$79,563 02
Expenditures, one year ended July 31, 1911—			
North Platte	$5,710 84		
Scottsbluff	3,898 26		
Valentine	13,640 21	$23,249 31	
Balances July 31, 1911—			
Culbertson	15,000 00		
North Platte	24,294 23		
Scottsbluff	4,715 76		
Valentine	12,303 72	56,313 71	

APPENDIX

THE PHOTOMETRIC AND THE COLORIMETRIC DETERMINATION OF HUMUS

BY F. J. ALWAY AND R. M. PINCKNEY

The determination of that portion of the organic matter of the soil which is soluble in dilute alkalies and which is known as humus (*matière noire* of Grandeau) is beset with various difficulties, which are well illustrated by the history of the method in use by the Association of Official Agricultural Chemists of the United States. The modification of the Grandeau method suggested by Hilgard, and in the following pages referred to as the *Hilgard method,* when properly carried out is capable of giving concordant and reliable results. With many soils, however, it is extremely tedious, the complete removal of the humus in some cases being accomplished only after from ten to twenty days of continuous extraction.[1] Partly in order to overcome this difficulty the Huston-McBride[2] method was adopted by the Association of Official Agricultural Chemists of the United States, about eighteen years ago, and has been retained up to the present time. While by this—now generally known as the "official"—method the time required for the determination of humus, where only a few soil samples are being analyzed, is greatly shortened, the results are entirely unreliable, the error amounting to from 15 per cent to over 200 per cent of the humus present.

The chief source of error in the accurate determination of humus lies in the difficulty of obtaining an ammonia extract which contains all of the humus while at the same time it is practically free from clay. Even if the extraction has been exhaustive and the extracts free from clay, the gravimetric determination, where a large number of samples are to be analyzed, is a slow process. Platinum evaporating dishes are required and, with the high price of platinum prevailing, the cost of each dish is between $60 and $100, and each dish will permit of the determination of but a single sample in duplicate in the course of twenty-four hours, the evaporation being continued night and day.

A few years ago, having occasion to make determinations of the humus in a large number of soil samples from different parts of Nebraska, and in a considerable number of samples from Saskatchewan, and wishing to know the approximate humus content of the different samples long before it could be learned from the gravimetric determinations, the humus extracts were prepared in lots of from 50 to 120 at a time and at once subjected to the photometric or the colorimetric determination described below. Then, as rapidly as was possible, gravimetric determinations were made in the case of all the extracts. Accordingly, we have a large amount of data from which to judge of the reliability of the methods. Part of these data are given in the following tables. At the time the determinations were made we did not appreciate the difficulty of removing the last traces of humus by the Hilgard method and accordingly many of the analyses were later rejected and new and more exhaustive extractions made, but on these no photometric determinations were made. This, however, probably does not affect the value of the earlier determinations for the study of the subject dealt with in this article.

The results lead us to the conclusion that for Nebraska soils very low in humus (under 0.30 per cent) the colorimetric method is as accurate as, or even more accurate than, the gravihumus content was low. The two methods are so similar in their essentials that they are to be regarded as different modifications of the same method, rather than as two distinct methods.

All the data on the following pages are from Nebraska and Saskatchewan soils, and we should here mention that in the case of a number of desert soils which we examined satisfactory results were not obtained.

THE STANDARD SOLUTIONS.—For both the photometric method and the colorimetric method the choice of a standard solution and the determination of the humus in it are of first importance. In the determinations reported below, the standard selected was the humus extract from a soil of the same type and from the same locality as the series of samples being analyzed. In some series a second standard from a different locality was used and is reported in order to show the extent to which the same standard may be used for soils from different localities. The determination of the humus in the standard solution was made gravimetrically.

THE PHOTOMETRIC METHOD.—As a source of light a candle is used, it being placed in a box with a hole half an inch in diameter in the top. The candle is held in a clamp 24 inches below the top of the box. Two Hehner cylinders, both of the same internal diameter, are connected by means of a rubber tube, both stop-cocks closed and the one cylinder partly filled with the standard solution. The empty cylinder is placed over the opening in the top of the box and the cylinder containing the standard solution supported on a stand at a height of 6 to 12 inches above the former. After lighting the candle and darkening the room as much as possible, the stop-cock of the higher cylinder is opened wide. While the operator has one hand on the stop-cock of the lower cylinder and has one eye above the latter, watching the candle flame, the solution is allowed to slowly enter until the flame just disappears. Then the stop-cock is closed and the height of the column of solution recorded, after which the lower cylinder is raised and the stop-cock opened so that part of the solution flows back into the other cylinder. Then the determination is repeated until two or three successive readings give approximately the same height, the average of these being used in the calculation.

After thus determining the depth of the column of the standard extract required to hide the candle flame, similar determinations were made with all the extracts. It much simplifies the calculations if in all cases equal weights of soil have been extracted and the extracts have been made up to the same volume. We used 10 grams of soil in each case and made the volume of extract up to 250, 500, or 1,000 c.c., according to the amount of ammonia solution required to fully extract the humus.

Where the same graduated cylinders, both of the same internal diameter, are used in all cases, it suffices to record the volume of the extract required to hide the candle flame. Otherwise, it is necessary to measure the depth of the column of solution. In case one of the pair of cylinders should be broken and another of different internal diameter should have to be substituted, it becomes necessary to employ a measuring stick and to record the height of the column of solution. In all cases it is desirable at the beginning of each series of determinations to enter in the record book the height of the 50 c.c. or 100 c.c. mark above the bottom of the cylinder. This will permit in the end the use of many different standards—as many as there are soils of which the humus has been determined gravimetrically, as well as photometrically.

Provided that the same weight of soil has been used and that the humus extracts have been made up to the same volume, the percentages of humus will be inversely proportional to the heights of the columns of extract required to hide the candle flame. Where the cylinders are of the same internal diameter and where, hence, the relative heights of the columns are the same as the relative volumes of solutions required, the volumes may be recorded and used in the calculations. The following extract from a page of a record book will illustrate the completeness and the character of the notes that we have found desirable:

Standard—Soil A. 10 grams extracted and extract made up to 500 c.c. For all soils in this series, weight of soil and volume of extract the same. Cylinders of the same internal diameter with 100 c.c mark at height of 152 mm.

Soil	Volume required	Humus
	c.c.	*Per cent*
A. Standard	52	2.20
A.	53	2.15
A.	54	2.22
A.	54	2.13
Average	53	2.18
B.	32	...
B.	31	....
Average	31.5	3.67
C.	57	....
C.	59	....
Average	58	1.99

THE COLORIMETRIC METHOD.—This is preferable in the case of dilute solutions of humus—those in which the humus solution to a depth of 150 mm. will not hide the candle flame. In this case a standard is prepared as above and then of this a measured volume is diluted to 100 c.c. or to 500 c.c., and an aliquot portion, say 50 c.c., is placed in a Hehner or a Nessler cylinder. This is held beside a similar, but empty, cylinder vertically over a white plate in a good light. To the empty cylinder the humus solution under examination is slowly added until the same tint is observed in both. The results are most accurate when the standard is diluted to such an extent that the diluted solution

Standard—Soil A. 10 grams extracted to make 500 c.c. extract. Humus, det'd gravimetrically=2.18 per cent. Diluted 50 c.c. of above extract to 500 c.c. and used 50 c.c. of the diluted standard. For all soils in this series, weight of soil was 10 grams and vol. of extract 250 c.c. Used cylinders of the same internal diameter. 100 c.c. mark at 152 mm.

Soil No.	Volume required	Humus
	c.c.	*Per cent*
Standard (A)	50	0.22
F	40	....
F	42	....
Average	41	0.27
G	63	....
G	65	....
Average	64	0.17

As, after one has become familiar with the method, over one hundred humus determinations can be made satisfactorily in the course of an eight-hour day, the gain in rapidity over the gravimetric method is evident. Of course the solutions require the same time for preparation and the humus in the standard must be determined gravimetrically.

Table 1 shows the percentages found by the photometric method compared with those found by the gravimetric in the case of 57 samples of soil from the Experimental Farm at Indian Head, Saskatchewan. All the samples were from the surface six inches. The history of the plots and fields, the method of sampling, etc., have already been given elsewhere.[3]

The photometric determinations were made on December 17, 1907, and were repeated on the following day. From these two sets of determinations it may be seen how concordant the photometric determinations are when the results are uninfluenced by a previous knowledge of the approximate depth of solution required to hide the candle flame. The average of the two photometric determinations is used in comparison with the gravimetric determination. In the table the samples are reported in the order of the percentage of humus as found by the gravimetric method. Thus, there is shown the concordance of the gravimetric determinations with the photometric, and the concordance of duplicate determinations by the latter method with one another. as well as the relative ranking of the samples when the humus has been determined by the two methods. In general the relative ranking is similar but not identical, those samples found to be rich, intermediate, or poor in humus by the one method being found to be rich, intermediate, or poor by the other method. altho the samples poor in humus may not have the same ranking. Three samples, 718, 719, and 731, gave decidedly lower results by the photometric method than by the gravimetric. The studies for which the gravimetric determinations were made have already been published.[3] If in these the results of the photometric determinations had been used instead of those of the gravimetric, the conclusions drawn would have been essentially the same. In this series of samples we have a great range in the humus content, viz., from 1.57 to 6.11 per cent.

TABLE 1.—*Humus in soils from the Indian Head Experimental Farm. For the standard, one of the series (No. 702) was used.*

Soil No.	Gravimetric	Photometric				Difference between gravimetric and photometric
		Dec. 17	Dec. 18	Average	Difference	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
703	6.11	6.67	6.81	6.74	.14	.63
725	5.98	5.14	4.99	5.07	—.15	—.91
727	4.82	4.39	4.15	4.27	—.14	—.55
728	4.22	3.83	3.64	3.73	—.19	—.49
717	3.25	2.68	2.52	2.60	—.16	—.65
715	3.02	2.77	2.49	2.63	—.28	—.39
732	2.92	2.40	2 26	2.33	—.14	—.59
735	2.88	3.00	2.90	2.95	—.10	.07
718	2.77	2.07	1.83	1.95	—.24	—.82
714	2.73	3.00	2.76	2.88	—.24	.15
716	2.71	2.77	2.68	2.72	—.09	.01
731	2.58	2.19	2.02	2.10	—.17	—.48

TABLE 1.—*Humus in soils from the Indian Head Experimental Farm—Concluded.*

Soil No.	Gravimetric	Photometric				Difference between gravimetric and photometric
		Dec. 17	Dec. 18	Average	Difference	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
719	2.53	1.83	1.80	1.81	—.03	—.72
681	2.49	2.25	2.07	2.16	—.18	—.33
736	2.48	2.72	2.52	2.62	—.20	.14
743	2.46	2.19	2.27	2.23	.08	—.23
742	2.32	2.17	2.12	2.15	—.05	—.17
704	2.30	2.25	2.27	2.26	.02	—.04
706	2.29	2.17	2.12	2.14	—.05	—.15
707	2.28	2.07	2.02	2.04	—.05	—.24
708	2.28	2.17	1.98	2.07	—.19	—.21
705	2.26	2.25	2.25	2.25	.00	—.01
741	2.24	2.07	2.05	2.06	—.02	—.18
729	2.23	1.85	1.82	1.84	—.03	—.39
696	2.21	2.07	2.02	2.05	—.05	—.16
739	2.16	1.87	1.81	1.84	—.06	—.32
682	2.13	2.00	1.87	1.93	—.13	—.20
738	2.12	2.02	1.87	1.94	—.15	—.18
737	2.10	2.02	1.78	1.90	—.24	—.20
697	2.10	2.04	1.93	1.98	—.11	—.12
687	2.07	2.04	2.00	2.02	—.04	—.05
698	2.05	2.00	1.93	1.97	—.07	—.08
681	2.05	1.87	1.89	1.88	.02	—.17
733	2.05	2.22	2.05	2.14	—.17	.09
690	2.05	2.09	2.10	2.09	.01	.04
709	2.03	1.93	1.74	1.83	—.19	—.20
699	2.03	2.14	2.02	2.08	—.12	—.05
702	2.00	2.00	2.00	2.00	...	...
692	2.00	2.04	2.02	2.03	—.02	.03
693	1.94	1.98	1.80	1.89	—.18	—.05
700	1.93	2.07	1.96	2.01	—.11	.08
701	1.93	2.07	1.93	2.00	—.14	.07
691	1.92	2.12	1.93	2.03	—.19	.11
683	1.92	1.68	1.71	1.70	.03	—.22
695	1.91	2.00	1.93	1.97	—.07	.06
684	1.90	1.95	1.89	1.92	—.06	.02
710	1.90	1.75	1.58	1.67	—.17	—.23
685	1.88	1.85	1.89	1.87	.04	—.01
694	1.87	1.95	1.85	1.90	—.10	.03
734	1.84	1.76	1.74	1.75	—.02	—.09
730	1.82	1.93	1.91	1.92	—.02	.10
689	1.79	1.78	1.81	1.80	.03	.01
688	1.78	1.93	1.80	1.86	—.13	.08
740	1.74	1.76	1.76	1.76	.00	.02
711	1.67	....	1.43	....	...	—.24
712	1.62	....	1.39	....	...	—.23
713	1.57	....	1.39	....	...	—.18

Table 2 shows the results where small individual samples of the surface six inches of soil from a virgin prairie in Lancaster county were compared. All the samples were taken with a brass tube 1⅜ inches in diameter, provided with a wide collar six inches from the end. The tube was driven into the ground until the collar rested firmly on the surface of the soil. In this series the range in the percentage of humus is much narrower than in the preceding series, viz., from 2.62 to 3.70 per cent.

TABLE 2.—*Humus in small individual samples from a prairie in Lancaster county. One of the samples (No. 423) was used as standard.*

Soil No.	Gravimetric	Photometric	Difference
	Per cent	*Per cent*	*Per cent*
435	3.70	3.28	— .42
430	3.65	3.07	— .58
410	3.47	2.98	— .49
431	3.45	2.87	— .58
433	3.40	2.91	— .49
414	3.40	2.33	—1.07
429	3.40	2.96	— .44
408	3.38	3.18	— .20
434	3.35	2.79	— .56
413	3.35	2.66	— .69
421	3.35	3.08	— .27
412	3.33	2.55	— .78
428	3.30	2.89	— .41
411	3.27	2.73	— .54
407	3.20	2.83	— .37
432	3.20	2.94	— .26
422	3.18	3.30	.12
406	3.12	2.87	— .25
415	3.05	2.32	— .73
427	3.05	2.86	— .19
401	3.00	2.75	— .25
405	2.97	2.69	— .28
404	2.95	2.77	— .18
419	2.95	2.58	— .37
420	2.95	2.39	— .56
409	2.92	2.46	— .46
402	2.90	2.78	— .12
425	2.90	2.86	— .04
416	2.85	2.29	— .56
424	2.85	2.86	.01
403	2.82	2.77	— .05
426	2.70	2.87	.17
417	2.65	2.42	— .23
418	2.62	2.41	— .21

TABLE 3.—*Humus in small individual samples from a prairie in Custer county. One of the samples was used as a standard.*

Soil No.	Gravimetric	Photometric	Difference
	Per cent	*Per cent*	*Per cent*
848	1.57	1.53	—.04
849	1.77	1.68	—.09
850	1.58	1.62	.04
851	1.80	1.93	.13
852	1.49	1.53	.04
853	1.48	1.44	—.04
854	1.33	1.32	—.01
855	1.67	1.79	.12
856	2.16	2.06	—.10
857	1.43	1.62	.19
858	1.68	1.80	.12
859	1.87	2.06	.19
860	1.44	1.44	...
861	1.53	1.71	.18

Table 3 shows the results from a series of 14 individual six-inch samples taken as above described from a virgin prairie in Custer county. The agreement with the gravimetric determinations is closer in this than in Table 2, due, perhaps, to the use of a better standard.

All the samples in Table 4 were composites of surface soil taken from various parts of Chase county and of Perkins county, some from prairies, others from long cultivated fields, some from the heaviest "hard land" and others from the most sandy land which has been brought under cultivation. The concordance of the two sets of determinations is much the same as that in Table 1. With this series, however, two standards were used but both were from soils belonging to the series. The results obtained by the use of the one were practically as satisfactory as those obtained by the use of the other.

Table 4.—*Humus in various samples from fields in Chase county and Perkins county. Two different standards were used, viz., a, 649, and b, 574.*

Soil No.	Gravimetric	Photometric*		Difference—	
		a	*b*	Between gravimetric and *a*	Between gravimetric and *b*
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
599	1.09	1.27	1.15	.18	.06
588	1.06	1.36	1.23	.30	.27
585	1.05	1.44	1.32	.39	.27
574	1.02	1.12	1.02	.10	...
592	.99	1.21	1.12	.22	.13
590	.93	1.21	1.12	.28	.19
649	.90	.90	.92	...	.02
674	.90	.84	.77	—.06	—.13
583	89	1.29	1.10	.40	.28
587	.87	1.08	.99	.21	.12
593	.87	.83	.75	—.04	—.12
595	.83	.94	.85	.11	.02
594	.81	.90	.82	.09	.01
584	.76	.95	.87	.19	.12
589	.72	.86	.78	.14	.06
591	.72	.89	.79	.17	.07
596	.73	.95	.87	.22	.14
600	.71	.92	.86	.21	.15
612	.71	.54	.49	—.17	—.22
577	.71	.81	.73	.10	.02
586	.70	.83	.75	.13	.05
597	.69	.86	.78	.17	.09
608	.65	.54	.48	—.11	—.17
613	.65	.59	.54	—.06	—.11
578	.62	.78	.72	.16	.10
661	.66	.89	.78	.23	.12
619	.62	.39	.35	—.23	—.27
660	.64	.84	.77	.20	.13
579	.60	.66	.60	.06	.00
614	.59	.57	.52	—.02	—.07
615	.51	.57	.52	.06	.01
617	.47	.43	.39	—.04	—.08
611	.44	.48	.43	.04	—.01
618	.38	.36	.31	—.02	—.07
620	.33	.41	.37	.08	.04

* In this and the following tables the colorimetric determinations are included in the column headed "photometric."

In Table 5 are given the data on a series of samples ranging in depth from one inch to four feet below the surface. These were taken from the walls of a trench dug for the purpose. The agreement is fairly satisfactory, except thru a layer of about six inches, located between the eleventh and the sixteenth inches, where the photometric readings indicated a much higher percentage of humus than was afterwards found by the gravimetric. The concordance of the results in the case of the samples of subsoil is striking.

TABLE 5.—*Humus from different depths in a trench in Perkins county. For the standard a bulk sample of surface six inches of soil from the same prairie was used.*

Soil No.	Depth	Gravimetric	Photometric	Difference
		Per cent	*Per cent*	*Per cent*
1150	1st inch	.92	.57	—.35
1151	2d "	.64	.69	.05
1152	3d "	66	.59	—.07
1153	4th "	.65	.54	—.11
1154	5th "	.65	.52	—.13
1155	6th "	.58	.57	—.01
1156	7th "	.65	.63	—.02
1157	8th "	.54	.60	.06
1158	9th "	.44	.56	.12
1159	10th "	.61	.69	.08
1160	11th "	.60	.95	.35
1161	12th "	.71	1.14	.43
1162	13th "	.93	1.60	.67
1163	14th "	1.06	1.72	.66
1164	15th "	.91	1.72	.81
1165	16th "	.84	1.47	.63
1166	17th "	1.07	1.06	—.01
1167	18th "	.53	.87	.34
1168	19th "	.42	.64	.22
1169	20th "	.44	.59	.15
1170	21st "	.35	.53	.18
1171	22d "	.34	.50	.16
1172	23d "	.36	.41	.05
1173	24th "	.32	.39	.07
1174	25-27 "	.26	.32	.06
1175	28-30 "	.15	.21	.06
1176	31-33 "	.09	.16	.07
1177	34-36 "	.09	.11	.02
1178	37-39 "	.06	.05	—.01
1179	40-42 "	.06	.03	—.03
1180	43-45 "	.07	.04	—.03
1181	46-48 "	.05	.04	.01

ment Station Farm. Two standards were used with part of the series. The one, "*a*", was one of the two used with the series given in Table 4, being from the western part of Nebraska. The other, "*b*", was a composite extract made by combining equal volumes of the extracts from four of the samples under examination, viz., 901, 902, 914, and 915, and determining gravimetrically the humus content. The second standard gave results agreeing closely with those obtained by the gravimetric determination, but the first gave, with part of the samples, results that were considerably too high.

TABLE 6.—*Humus in the surface foot of soil in various plots on the Experiment Station Farm.*

Soil No.	Gravimetric	Photometric		Difference between—	
		a W. Nebr. standard 649	*b* E. Nebr. standard	Gravimetric and photometric *a*	Gravimetric and photometric *b*
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
902	2.68	3.55	2.83	.87	.15
903	2.44	3.29	2.62	.85	.18
901	2.29	2.86	2.28	.57	—.01
916	1.91	2.39	1.91	.48	...
914	1.85	2.29	1.82	.44	—.03
912	1.89	1.83	....	—.06	...
917	1.88	2.29	1.82	.41	—.06
915	1.80	2.39	1.91	.49	.11
913	1.77	2.01	....	.24	...
908	1.32	1.37	....	.05	...
910	1.31	1.49	....	.18	...
911	1.24	1.28	...	.04	...
909	1.23	1.08	....	—.15	...
905	1.12	1.07	.85	—.05	—.57
907	.99	.75	....	—.24	...
904	.92	.72	.85	—.20	—.07

In order to determine the availability of the photometric method for determinations of the so-called humus as obtained by the "official" method, 20 samples taken from a bulk sample treated by the "official" method and the other half by the Hilgard method. The solutions obtained by the latter method were diluted to 500 c.c. When the solutions had all been prepared, the humus was determined, first by the photometric method and then by the gravimetric method. The results are given in Table 7, in which the determinations are reported in the order of the content of humus ash. The standard used was a humus extract obtained from the same soil by the Hilgard method.

TABLE 7.—*Comparison of the Hilgard method with the "official" method.*

	Gravimetric methods				Photometric method	
	Humus		Humus ash		Humus	
	Official	Hilgard	Official	Hilgard	Official	Hilgard
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1........	1.97	.70	7.20	.32	1.64	.88
2........	1.92	.89	7.01	.29	1.80	.89
3........	1.79	.75	6.21	.26	1.95	.80
4........	1.90	.83	6.10	.26	1.70	.87
5.......	1.65	.85	5.63	.26	2.53	.80
6.......	1.68	.78	5.58	.26	1.61	.89
7.......	1.73	.89	5.36	.25	1.75	.89
8.......	1.71	1.01	4.80	.21	1.64	.87
9........	1.43	.77	3.84	.21	2.09	.80
10........	1.45	.71	3.46	.20	1.65	.77
Average	1.72	.82	5.52	.25	1.84	.85

While the amount of humus found by the "official" method increased in general with the amount of humus ash, this was not the case with the data obtained by the photometric determination of the same solutions. While the average of the results obtained by the photometric method agreed very well with the average of those obtained by the gravimetric method, this was due to the comparatively large number of determinations made. The individual determinations varied from 1.64 to 2.53 per cent, whereas the gravimetric determinations varied only from 1.43 to 1.97 per cent.

The best conditions for the use of the photometric method require, first, that the solution be kept as concentrated as is possible without too great inconvenience in securing complete extraction, and second, that a typical soil from the same region be used in the preparation of the standard.

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THE MINERAL CONSTITUENTS OF SOME SOILS OF THE EASTERN NEBRASKA LOESS

By F. J. Alway and E. K. Files

The soils the analyses of which are reported in the following pages were taken from what are to be regarded as strictly loess areas. They belong to three fairly distinct types. The one having by far the most extensive distribution is represented by the samples reported in Tables 1, 4, 5, and 6*b*. In this type, which occurs on the high, level, or gently rolling lands, the surface is being gradually lowered by erosion. On it there has probably been little deposition of soil by either wind or water. A second type, having a limited distribution, is represented by the samples reported in Tables 2, 6*a*, and 6*c*. This is the lowland soil which occurs adjacent to the preceding. It is found along creeks, "runs," and still shallower depressions thru which water flows after heavy rains. Wherever it is protected by a dense covering of vegetation it is still being added to and in some cases an addition of transported soil occurs even in the case of bare, cultivated fields. The material deposited on it is derived either entirely, or chiefly, from the erosion of the surface soil of the preceding type. The third type of loess soil is represented in Tables 3, 7, and 8. This lies in a broad plain which locally is known as a valley, it having higher lands on both sides It is at no great distance from the edge of the great area of Nebraska sand hills. This type of soil gives no evidence of having in recent times received an appreciable addition of soil by deposition from water. It was, evidently, laid down under conditions quite different from those prevailing in the case of the first type. The soils belonging to the first two types analyzed are all from Lancaster county, of which the Bureau of Soils of the United States Department of Agriculture has recently made a survey.[1] On the Bureau of Soils map the two types are shown as Marshall Silt Loam and as Wabash Silt Loam, respectively.

The samples from the first two types were taken in 1907 and those from the other in 1908 in connection with a study of the changes in the amount of nitrogen, humus, and total organic matter that have been induced by cultivation.[2] In the summer of 1908, as a preliminary investigation of the mineral constituents of the loess soils of Nebraska, the acid-soluble potash and soda, and incidentally the acid-insoluble matter, were determined by R. A. Gortner, and the acid-soluble phosphoric acid by W. D. Bonner and C. E. Vail. The portions of the solutions remaining after the determination of the potash in duplicate were saved in glass flasks (not Jena). During the following winter the junior author determined the lime in part of the solutions and still later the rest of the mineral constituents. Where the duplicate determinations were not concordant and all of the "solutions A" had been used, the results are not reported in the tables. The preparation of the "solutions A" is an operation involving much time, and only a very small amount of money was available to meet the expenses of the work. The large number of analyses reported would not have been possible with the small sum of money available had it not been that the junior author was a graduate student working on his thesis. The tables below are part of the data finally presented in his thesis for the Master's degree.

METHODS OF SAMPLING

The samples to a depth of six inches were secured by means of a brass tube 1⅜ inches in diameter and provided with a wide brass collar 6 inches from the end. The tube was forced into vidual cores taken with the tube. To obtain inch sections for analysis, cores obtained as above were subdivided.

In the case of the first foot of soil from the first prairie sampled, the surface six-inch cores were divided into five equal sections as were also the second six-inch cores. Thus, the first. fifth, sixth, and tenth sections correspond to the first, sixth, seventh, and twelfth sections from the other two prairies.

For samples of soil from below the first foot two augers were used, the one of 1¾ inch and the other of 1 inch diameter. The larger auger was used to remove the first foot of soil, after which the smaller was employed to obtain the sample of the second foot. The larger auger was next used to enlarge the hole to the bottom of the second foot. Then by means of the small auger the third foot samples were taken. This process was continued for the still lower portions of the soil. If a single auger had been used the samples from below the first foot would have been more or less affected by material from nearer the surface adhering to them.

The number of individual samples used in making the composite samples analyzed was too small to be satisfactory for a study of the acid soluble mineral components, altho satisfactory for the purpose for which the samples were taken. For this reason the number of individual samples used in making the composites becomes important and is indicated below in the description of the different tables.

METHODS OF ANALYSIS

The determinations of potash, phosphoric acid, and lime were made by the Hilgard methods for the acid digestion of soils. For phosphoric acid the ignited soil was digested with strong nitric acid for two days on the steam bath. For the other constituents the methods of the A. O. A. C.[3] were used after the so called "solution A" had been prepared by the digestion of the soil for 120 hours with hydrochloric acid (instead of for 10 hours, the time of digestion adopted by the A. O. A. C.) and the removal of the dissolved silica.

THE SURFACE FOOT OF VIRGIN PRAIRIES

In the case of three virgin pariries ten cores taken to a depth of one foot were subdivided, in the case of the first into ten and in that of the other two into twelve parts. The first prairie (Table 1), which is less than half a mile from the Nebraska Experiment Station farm, has since 1889 formed a part of the campus of the Nebraska Wesleyan University. The portion from which the samples were taken has since that time been mown annually for hay; during the rest of the year it has been little visited except by children in search of wild flowers. Previous to 1889 it had formed part of a large pasture. It is typical of the virgin upland prairie of eastern Nebraska. The loess varies from 15 to 20 feet in depth, it being underlaid with boulder clay.

The samples reported in Table 2 are from the lower, level portion of what is known as Peck's Grove, which is situated a few hundred yards south of the Experiment Station. Some thirty or forty years ago cottonwood trees were planted in the prairie and since then the soil has been left undisturbed. The lower portion of the grove, where the samples were taken, is flooded after torrential rains.

The third prairie (Table 3) is near Elgin on the farm of the Hon. George Coupland, who has used it as a pasture for over thirty years. Previous to that the whole farm was part of the unfenced public domain.

There are no marked differences in the mineral composition of the different inch sections except that the surface inch is distinctly higher in volatile matter than the lower sections.

THE FIRST SIX FEET OF VIRGIN PRAIRIES

Table 4 gives the data on the samples from the prairie on the

Experiment Station Farm. The data in Table 6 are from the Experiment Station Farm pasture thru which passes the water course known as Dead Man's Run. The lowland portion (6*a*) is inundated at times of very high water, after which a heavy deposit of soil is to be found covering the surface. The grass soon grows above this, however, and at the end of a few weeks there is little evidence of the high water left. In 6*c* is given the analysis of a composite of a large number of samples collected just after an overflow of Dead Man's Run in April, 1908. The soils reported in Table 6*a* are of the same type as those reported in Table 2. The black soil extends to a depth of from 3 to 5 feet. The samples analyzed were composites from five borings. The upland portion of the pasture, from three borings in which the samples reported in 6*b* were taken, slopes to the north and east. It receives no deposit from high water, but on the contrary it is exposed to considerable erosion. The samples reported in Table 7 are composites from two borings from the same prairie as those reported in Table 3. Those in Table 8 are from the farm of Mr. A. Perry, four miles north of Elgin. They also are composites from two borings.

The set of samples reported in Table 9 is from a single boring near the residence of Mr. Coupland. At this point the loess sheet has a thickness of about 36 feet.

THE SURFACE SOIL FROM ADJACENT FIELDS AND PLOTS

In Table 10 the composition of samples from adjacent fields and plots on the Experiment Station Farm is reported. For the samples of the surface six inches of soil six cores were used and for those of the first foot of soil four borings were made.

1.—*Surface foot of soil from prairie at Lincoln (Nebraska Wesleyan University campus).*

	Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
First tenth......	77.44	.55	.27	.40	.55	3.24	5.90	.09	.04	11.26	100.07
Second tenth ...	78.77	.57	.17	.47	.43	3.08	6.78	.08	.04	9.60	99.99
Third tenth......	78.79	.60	.24	.48	.40	3.04	7.06	.09	.04	9.12	99.86
Fourth tenth....	78.65	.64	.41	.51	.46	3.04	7.76	.09	.04	9.04	100.67
Fifth tenth......	78.52	.63	.38	.52	.63	3.12	7.37	.11	.06	8.34	99.74
Sixth tenth.....	79.67	.64	.29	.55	.57	3.44	6.90	.08	.05	8.42	100.63
Seventh tenth...	79.28	.70	.25	.50	.62	3.28	7.56	.07	.06	8.18	100.41
Eighth tenth...	79.45	.68	.16	.47	.57	3.44	7.92	.08	.05	8.09	101.01
Ninth tenth.....	80.24	.64	.30	.44	.65	3.12	7.60	.08	.05	7.78	100.90
Tenth tenth.....	79.39	.69	.27	.42	.60	3.72	7.88	.09	.06	7.40	100.52
verage....	79.05	.63	.28	.48	.55	3.25	7.27	.09	.05	8.72	100.37

TABLE 2.—*Surface foot of soil from prairie at Lincoln (Peck's Grove).*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1469	First inch.......	73.63	.88	.43	.70	.61	3.74	7.17	.07	.06	13.25	100.27
1470	Second inch.....	78.44	.61	.13	.95	.73	2.47	5.81	...	.07	10.54	......
1471	Third inch.......	79.88	.67	.26	.88	.49	2.41	6.02	.07	.06	8.60	99.34
1472	Fourth inch... .	80.76	.65	.11	.85	.49	3.06	5.34	.07	.05	7.90	99.28
1473	Fifth inch.......	83.13	.56	.18	.75	.63	2.78	5.91	.07	.05	7.23	101.29
1474	Sixth inch.	81.94	.68	.15	.73	.56	2.89	5.42	.06	.05	6.91	99.39
1475	Seventh inch....	82.96	.60	.18	.75	.60	3.14	4.97	.06	.06	6.79	100.11
1476	Eighth inch.....	.....	.57	.21	.79	.54	3.14	5.07	.06	.05	6.58	.....
1477	Ninth inch	83.18	.62	.23	.80	.55	3.24	5.21	.09	.05	6.35	100.32
1478	Tenth inch......	.....	.71	.15	.65	.50	2.47	5.81	.09	.05	5.83	......
1479	Eleventh inch...	83.24	.63	.13	.72	...	2.15	6.26	.06	.06	6.03	......
1480	**Twelfth inch**.....	82.54	.68	.22	.75	.49	2.41	6.12	.05	.07	5.74	99.07
	Average....	80.97	.65	.18	.78	.56	2.82	5.77	.06	.06	7.63	99.48

TABLE 3.—*Surface foot of soil from prairie near Elgin, Antelope County.*

	Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
irst inch.......	84.50	.49	.13	.35	.49	2.52	4.43	.07	.04	8.00	100.93
cond inch.....	84.71	.40	.08	.50	.51	1.88	4.11	.08	.04	7.26	99.57
ird inch.......	85.10	.44	.07	.60	.63	2.40	4.73	.08	.05	7.80	101.90
urth inch.....	85.81	...	...	.62	.82	2.96	5.14	.06	.04	7.89	......
ifth inch.......	84.34	.45	.08	.41	.50	2.80	4.93	.06	.05	7.88	101.50
ixth inch.......	85.21	.41	.12	.30	...	....	....	.09	.05	7.78	......
eventh inch....	82.25	...	...	.39	.67	....	....	...	.04	7.51	......
ighth inch.....	84.65	.53	.10	.40	.60	2.96	5.59	.08	.04	7.24	102.19
inth inch......	84.87	.49	.13	.34	.63	3.00	4.95	.06	.06	7.01	101.54
enth inch......	84.91	.50	.10	.28	.69	2.52	5.83	.07	.07	6.80	101.75
leventh inch...	85.61	.50	.12	.30	...	2.76	5.12	.05	.04	6.59	101.29
welfth inch....	85.38	.48	.14	.41	.47	2.76	4.91	.06	.05	6.78	100.44
verage	84.68	.47	.11	.41	.56	2.66	4.97	.07	.04	7.38	101.35

ABLE 4.—*First six feet of soil from prairie at Lincoln (Nebraska Wesleyan University campus).*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
6-525	First foot......	79.05	.63	.28	.48	.55	3.25	7.27	.09	.05	8.72	100.37
8	Second foot....	73.50	.77	.32	.70	1.26	4.61	10.87	.07	.04	8.02	100.16
9	Third foot	75.13	.91	.21	1.07	1.03	4.76	10.76	.10	.05	6.81	100.83
0	Fourth foot ...	76.58	1.01	.13	1.66	....	4.28	9.83	.14	.06	6.29	......
1	Fifth foot	77.45	....	...	.86	....	....	.....	.14	.05	5.62	......
2	Sixth foot......	79.73	....	...	.84	....	....	.....	.14	.04	5.55	......

.—Composite samples from fields adjacent to the Experiment Station Farm, Lincoln.

	Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
st foot.......	78.46	.69	.19	.68	.78	3.71	8.84	.05	.07	7.87	101.45
ond foot......	75.68	.94	.15	1.03	1.25	4.24	. .	.06	.09	8.25	......
rd foot.......	76.51	.97	.26	1.20	1.19	4.64	10.71	.11	.06	5.83	101.48
rth foot.....	77.52	.97	...	1.54	1.35	3.88	10.25	.13	.06	4.65	101.35
h foot.......	77.90	.96	...	1.51	1.03	4.32	.....	.15	.04	4 21	100.56
h foot.......	.....	.97	...	1.07	1.06	4 27	.....	.13	.04	5.12	......
age..........	77 23	.91	...	1.17	1.11	4.18	.....	.10	.06	5.99	.....

TABLE 6.—*Pasture field on Experiment Station Farm, Lincoln.*

	Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
a. LOWLAND PORTION.											
t...	78.60	.73	.27	.74	.77	3.21	7.24	.07	.07	8.74	100.44
foot.....	81.17	.61	.24	.84	.55	3.28	6.18	.10	.05	7.46	100.48
t.......	79.82	.75	.24	.83	.59	3.82	7.68	.10	.05	6.58	100.46
oot	84.39	.73	.10	.51	...	3.31	7.13	.09	...	4.25	100.51
ot.......	86.71	.81	.40	.70	.82	....	....	.09	.06	...	......
ot.	79.77	.86	.23	.91	...	3.98	7.86	.09	.05	5.08	......
....	81.74	.75	.25	.76	...	3.51	7.40	.09	.06	6.43	......
b. UPLAND PORTION.											
ot.......	79.00	.76	.18	.40	.64	3.42	7.93	.08	.07	8.46	100.94
foot.....	75.08	1.04	.21	.63	1.09	4.10	10.10	...	.07	7.42	......
ot.......	77.00	.87	.29	.98	1.31	4.66	7.08	...	.07	5.64	......
....	77.03	.89	.23	.67	1.01	4.06	8.37	..	.07	7.17	.....
c. FLOOD DEPOSIT.											
eposit...	80.29	.72	.32	.57	.87	....	.....	.06	.05	7.02	.....

TABLE 7.—*First six feet of soil from prairie in Antelope County.*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
	*First foot.......	84.68	.47	.11	.41	.56	2.66	4.97	.07	.04	7.38	101.35
1625	Second foot.....	86.11	.47	.16	.66	..	2.65	5.60	.06	.05	4.16	100.01
1626	Third foot.......	83.46	...	...	.58	.68	2.80	7.23	.07	.06	4.09	......
1627	Fourth foot......	87.69	.48	.15	.84	.57	2.60	6.27	.07	.06	3.25	101.98
1628	Fifth foot.......	86.07	.47	.15	.50	.64	2.95	5.34	.09	...	4.21	100.42
1629	Sixth foot.......	88.14	.50	.14	.50	.65	2.75	4.72	.08	.07	3.62	101.86
	Average	86.03	.48	.14	.58	.62	2.73	5.70	.07	.06	4.45	100.86

* Average of 1610 to 1621.

TABLE 8.—*First six feet of soil from prairie on farm of A. Perry, Antelope County*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1658	First foot	82.71	.57	.19	.96	.76	3.00	5 51	.08	...	7.38	100.40
1659	Second foot......	80.80	.58	.22	4.04	...	3.40	6.97	.11	.05	....	.. ..
1660	Third and fourth foot	77 09	.63	.12	4.44	...	3 00	5.96	.15	.04	7.79	99.22
1661	Fifth foot.	78.00	.61	.17	4.21	...	3 20	6.37	.14	.04	...	......
1662	Sixth foot.......	71.37	.62	17	4.77	...	3.40	6.11	.14	.04	....	......
	Average...... ...	78.64	.61	.16	3 61	...	3.16	6.14	.13	.04	....	......

TABLE 9.—*Deep subsoil from a field in Antelope County.*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1707	7 to 9 ft........	76.23	1.11	.33	3.04	1.43	3.88	8.82	.14	.08	....	....
1711	10 to 12 ft........	75.50	1.07	.32	2.82	1.38	3.92	9.25	.14	.07	....	....
1715	12 to 14 ft........	75.31	1.23	.38	2.64	....	3.76	8.63	.15	.04	....	....
1719	16 to 18 ft........	74.96	1.22	.51	2.88	1.44	4.10	8.80	.15	.06	....	....
1722	19 to 20 ft........	75.42	1.21	.28	2.90	....	....	....	.15	...	....	....

).—*Surface soil from fields on or near the Experiment Station farm, Lincoln.*

FIRST SIX INCHES.

	Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
grove..	80.66	.62	.20	.70	.61	....	....	.07	...	8.72	......
asture.	79.08	.75	.23	.62	.72	4.08	4.70	.06	...	9.76	......
sture..	78.49	.77	.21	.55	.74	3.18	6.93	.06	.05	9.08	100.04
falfa..	81.41	.77	...	...	...	....	....	.07	.06	7.14	......
chard..	78.67	.92	.20	.54	.83	3.36	....	.08	.06	7.11	......
falfa (2)	80.45	.69	.12	.52	.75	3.48	7.20	.07	.05	7.58	100.91
ass plot	79.65	.87	.28	...	.60	3.34	6.82	...	.06	9.01	......
ng cul- ield....	79.92	.75	.23	.51	.64	3.26	5.99	...	.06	8.66	100.02

FIRST TWELVE INCHES.

	Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
rove...	82.02	.63	.19	.66	.56	2.40	5.70	.07	.06	8.23	100.52
asture.	80.73	.63	.18	.53	.59	2.97	6.62	.07	.07	9.15	101.54
sture..	78.80	.78	.14	.54	.77	3.60	6.74	.07	.05	8.72	100.21
falfa...	77.55	...	...	.53	.74	...	..	...	.07	7.59	......
chard..	79.84	.76	...	.51	.76	3.48	7.42	.07	.05	7.33	100.22
lfalfa (2)	79.97	.82	...	.55	.80	3 20	7.17	.06	.05	7.40	100.02
ass plot	80.91	.74	...	.60	.55	2.85	7.80	...	.05	8.19	......
ng cul- ield...	80.64	.74	...	.55	.56	3.00	6.72	...	.05	8.06	......

1.—*Surface six-inch samples from various fields on the farms of Mr. George Coupland and his neighbors.*

Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
82.63	.54	.12	.48	.61	...	...	.08	.06	7.79	......
88.00	.43	.16	.43	.45	2.24	4.21	.06	. .	4.12	100.10
85.26	.45	.11	.51	.50	....	....	.06	.03	6.41	......
86.69	.41	.09	.50	.45	...	....	.06	.04	5.31	......
86.59	.45	.14	.50	.40	2.40	4.88	.06	.06	5.13	100.61
84.93	.56	.12	.49	.48	....	...	.07	.04	5.59	......
84.23	.62	.12	.53	.52	2.85	5.69	.06	.04	5.95	100.61
84.35	.51	.12	.44	.60	2.87	5.32	.07	.05	7.05	101.38
85.00	.46	.14	.47	.62	2.95	5.00	.06	.05	6.69	101.44
84.50	.51	.12	.46	.46	3.10	5.56	.07	.06	6.86	101.70
84.81	.50	.16	.48	.66	3.05	5.02	.08	.04	5.95	100.75
82.06	.59	.16	.47	...	3.05	....	.08	.05	7.96	......
83.09	.56	.20	.62	.78	3.10	6.10	.08	.04	7.16	101.73
90.40	.33	.13	.54	.38	2.45	2.31	.08	.04	4.89	101.55
86.67	.43	.14	.49	.58	2.80	3.37	.07	.05	5.75	100.35
84.35	.51	.16	.59	.43	2.60	4.65	.07	.06	7.58	100.99
88.41	.40	.11	.53	.42	2.20	3.94	.06	.05	5.10	101.22
87.70	.42	.16	.44	.37	3.00	4.70	.06	.05	5.28	100.18
84.54	.51	.15	.44	.40	3.47	5.07	.08	.05	6.94	101.65
87.70	.40	.13	.45	.52	....	...	.08	.05	5.55	......
86.45	.41	.16	.45	.47	2.50	4.05	.06	.07	6.00	100.62
83.75	.52	.12	.46	.60	3.00	4.50	.08	.05	7.75	100.83
85.59	.46	.15	.39	...	3.00	4.85	.09	.04	....	......
84.83	.55	.18	.36	...	....	....	.08	...	6.61	.....

1638 and 1639 are composites of four one-foot samples corresponding to Nos. 1637 and 1636 respectively.

ample is a composite of 10 individual samples.

ample is a composite of 6 individual samples.

TABLE 12.—*Analysis of the same soil on different days.*

No. of analysis	Potash K_2O	Soda Na_2O
1	.90	.29
2	.87	.32
3	.88	.35
4	.89	.39
5	.91	.35
6	.87	.29
7	.86	.29
8	.91	.31
9	.88	.29
10	.91	.27
11	.91	.27
Average	.89	.31
Highest	.91	.39
Lowest	.87	.27

From these analyses of surface soils it is evident that it is futile to attempt to find differences in the amount of the mineral constituents which have been caused by cultivation, unless the samples analyzed are composites of at least a very large number of individual samples.

An exhaustive study of the chemical composition of the soils of the loess prairies of Nebraska is now being made at this Experiment Station, the composite samples used being composed of from 50 to 100 individual samples.

REFERENCES

1. Soil Survey of Lancaster Co., Nebraska. Bur. of Soils (1908).
2. Alway: Changes in the Composition of the Loess Soils of Nebraska Caused by Cultivation, Bul. 111, Nebr. Exp. Sta.

ON THE SAMPLING OF PRAIRIE SOILS

BY F. J. ALWAY AND R. S. TRUMBULL

The surface soil of cultivated fields tends to become uniform on account of the constant stirring and mixing to which it is subjected in the course of tillage operations. In the case of the surface soil of prairies there is no such action tending to produce uniformity. Slight differences in texture tend to produce marked differences in the chemical composition. This is well illustrated in the case of some prairie soils which we have described elsewhere.[1] In order that comparisons of any value may be made of the composition of surface soils of prairies with those from cultivated fields, methods of sampling must be used which give samples that are really representative. In some cases it seems almost impossible to obtain an entirely satisfactory sample of the prairie soil for such purposes of comparison. First among the things to be considered in this connection are the number of individual samples that must be taken in order to make a representative composite and the influence upon the composition of the sample of slight differences in the depth to which it is taken. As preliminary to the study of the surface soils of Nebraska prairies, the greater part of the data given in the following tables was collected.

METHODS OF SAMPLING

The samples to a depth of 6 inches were secured by means of a brass tube $1\frac{3}{8}$ inches in diameter and provided with a wide brass collar 6 inches from the end. The tube was forced into the ground by the operator standing on it or jumping upon it until the collar rested firmly upon the surface. For samples of the second six inches of soil, the same tube was used after removing the first six inches by means of a spade.

The individual samples were taken at certain intervals, any distinct irregularities on the surface, such as paths, trails, mounds, etc., being avoided. Usually the members of a series of samples were in a straight line across the prairie. The vegetation was clipped off level with the surface but all plant residues as well as roots, insects, etc., were treated as an integral part of the soil, for the reason that these carry nitrogen in its most readily available form.

METHODS OF ANALYSIS

The nitrogen was determined by the ordinary Kjeldahl method and the humus by the Hilgard method, the ammonia being applied continuously until the washings were colorless. This, as has been shown previously,[2] may leave a little of the humus unextracted, but with the soil types in question this residue would be insignificant, the percentage of unextracted humus being less than the differences between duplicate determinations of the same soil. This has been discussed in detail in Bulletin 115 of the Nebraska Experiment Station, the data being given in Tables II and III of that bulletin, and the soils reported as Nos. I, II and III are representative of the three types of soil dealt with in the following pages. The percentages of humus ash, where determined, are given as evidence of the reliability of the humus determinations.

In the case of different samples where the weight of the cores is reported the soil was dried at 110° C. before weighing.

SAMPLES FROM PRAIRIES ON THE LOESS AREA

LANCASTER COUNTY.—The series of samples reported in Table 1 was taken in August, 1907, from a portion of the campus of the Nebraska Wesleyan University, described elsewhere in this Report. In the case of four groups of five samples each, the cores were taken only two inches apart, the groups being at intervals of 60 yards. The other samples were taken at intervals of 30 feet.

The humus contained in the 35 individual samples ranged from 2.65 per cent to 3.70 per cent and the nitrogen from 0.250 per cent to 0.317 per cent. Thus the differences between the extremes in the case of both constituents amount to over 30 per cent of the quantity present in the sample with the smallest amount. Even in the case of the groups of five samples taken close together the differences between extremes amount to as high as 15 per cent. Thus the differences found between individual samples taken close together are as great as those found between the soil of long-cultivated fields and that of the adjacent virgin prairies.[8] That the differences become less when composites of a number of individual samples are used is shown in Table 2. By using a composite of five samples the extremes would have become, for humus, 3.42 per cent and 2.81 per cent, and for nitrogen, 0.304 per cent and 0.276 per cent, the differences becoming half or less of what they were found to be when the individual samples were compared. By combining from 10 to 15 individual samples as composites for analysis, the extremes would have been, for humus, 3.05 and 3.34 per cent, and for nitrogen 0.281 and 0.297 per cent, the differences being half as great as with the composites of five. By increasing the number of individual samples used for the composites to 20, the differences between the different composites would have become less than the experimental error of analysis. The greatest variations are in the humus content and it is to be observed that the humus content does not rise and fall with that of the nitrogen when only individual samples are compared. This is to be attributed to the varying amounts of roots, unhumified plant residues, insects, etc., in the individual samples. These parts of the samples, while rich in nitrogen, contain no humus.

maximum error would have been approximately ten per cent in the case of humus and approximately five per cent in the case of nitrogen.

TABLE 1.—*Composition of individual samples from the prairie on Nebraska Wesleyan University campus.*

Sample No.	Distance from preceding sample	Humus	Nitrogen	Weight of 6 inch sample	Ratio of humus to nitrogen
		Per cent	*Per cent*	*Grams*	
1		3.00	.275	134.1	10.9
2	2 inches	2.90	.276	132.9	10.5
3	2 inches	2.82	.283	120.9	10.0
4	2 inches	2.95	.277	117.6	10.6
5	2 inches	2.97	.268	126.7	11.1
6	30 feet	3.12	.287	133.0	10.8
7	30 feet	3.20	.288	121.2	11.1
8	30 feet	3.37	.301	118.8	11.2
9	30 feet	2.92	.250	132.7	11.7
10	30 feet	3.47	.306	128.2	11.3
11	30 feet	3.27	.294	116.7	11.1
12	2 inches	3.33	.293	115.7	11.4
13	2 inches	3.35	.312	113.7	10.7
14	2 inches	3.40	.313	113.1	10.9
15	2 inches	3.05	.306	132.3	10.0
16	30 feet	2.85	.278	127.5	10.3
17	30 feet	2.65	.317	125.3	8.4
18	30 feet	2.67	.278	127.0	9.6
19	30 feet	2.95	.303	131.8	9.7
20	30 feet	2.95	.279	124.9	10.6
21	30 feet	3.35	.299	108.4	11.2
22	2 inches	3.17	.291	125.1	10.9
23	2 inches	3.10	.313	113.7	9.9
24	2 inches	2.85	.296	122.1	9.6
25	2 inches	2.90	.278	125.7	10.4
26	30 feet	2.90	.270	122.6	10.7
27	30 feet	3.05	.286	112.6	10.7
28	30 feet	3.30	.289	108.7	11.4
29	30 feet	3.40	.291	129.7	11.7
30	30 feet	3.65	.302	114.6	12.1
31	30 feet	3.45	.298	132.4	11.6
32	2 inches	3.20	.285	124.3	11.2
33	2 inches	3.40	.306	124.1	11.1
34	2 inches	3.35	.279	127.7	12.0
35	2 inches	3.70	.291	121.9	12.7
	Average of all	3.14	.290	124.2	10.8

TABLE 2.—*The concordance of results obtained by increasing the number of samples used in making a composite.*

	Weight	Humus	Nitrogen	Ratio of humus to nitrogen
	Grams	*Per cent*	*Per cent*	
First five	134.4	2.93	0.276	10.6
Second five	126.8	3.22	0.286	11.3
Third five	118.3	3.28	0.304	10.8
Fourth five	127.3	2.81	0.291	9.7
Fifth five	119.0	3.07	0.295	10.4
Sixth five	117.6	3.26	0.288	11.3
Seventh five	126.1	3.42	0.292	11.7
First ten	130.6	3.08	0.281	10.9
Intermediate fifteen	121.5	3.05	0.297	10.3
Last ten	121.9	3.34	0.290	11.5
First twenty	126.7	3.06	0.289	10.6
Last twenty	122.5	3.14	0.291	10.8
Average of all	124.2	3.14	0.290	10.8

The humus and nitrogen contained in the surface soil of virgin prairies decreases rapidly from the surface downward, as is shown in Table 3. Hence, if, in sampling, the samples were more compacted, as by a heavy man jumping upon the sampler to force it into the ground or by the surface having been trodden by the feet of pasturing animals, a deeper section would unconsciously be taken. Also, the samples taken early in the spring or after a heavy rain might be deeper than usual. Such differences would be revealed by the weight of the dry samples, the lighter the sample the shallower the penetration of the sampler having actually been. The heavier the individual samples the lower the nitrogen and humus would be expected to be. To show the actual relation between the weight of the core and its composition, the data are arranged in Table 4 in the order of the weights of the individual cores. It will be seen that when individual samples are compared there is no direct relation between the weight and the composition of the sample. When groups of five or ten are compared, there is, however, a decrease in the content of nitrogen accompanying an increase in the weight of the sample.

TABLE 3.—*The average content of nitrogen and humus at different depths in the surface foot of prairies on the Nebraska loess.**

	Nitrogen	Humus
	Per cent	*Per cent*
First inch	.360	3.64
Second inch	.292	3.01
Third inch	.247	2.88
Fourth inch	.222	2.41
Fifth inch	.209	2.35
Sixth inch	.199	2.40
Seventh inch	.188	2.23
Eighth inch	.179	2.27
Ninth inch	.170	2.04
Tenth inch	.163	1.79
Eleventh inch	.155	1.91
Twelfth inch	.151	1.48

* From Tables VIII and XII, Bulletin 111, Nebraska Experiment Station.

TABLE 4.—*Data in Table 1 rearranged to show the relation between the weights of the samples and their composition.*

Sample No.	Weight of six-inch sample	Humus	Nitrogen	Ratio of humus to nitrogen
	Grams	*Per cent*	*Per cent*	
21	108.4	3.35	.299	11.2
28	108.7	3.30	.289	11.4
27	112.6	3.05	.286	10.7
14	113.1	3.40	.313	10 9
13	113.7	3.35	.312	10.7
23	113.7	3.10	.313	9.9
30	114.6	3.65	.302	11.8
12	115.7	3 33	.293	11.4
11	116.7	3.27	.294	11.1
4	117.6	2.95	.277	10.7
8	118.8	3.37	.301	11.2
3	120.9	2.82	.283	10.0
7	121.2	3.20	.288	11.1
35	121.9	3.70	.291	12.7
24	122.1	2.85	.296	9.6

TABLE 4.—*Data in Table 1 rearranged to show the relation between the weights of the samples and their composition—Concluded.*

Sample No.	Weight of six-inch sample	Humus	Nitrogen	Ratio of humus to nitrogen
	Grams	*Per cent*	*Per cent*	
26	122.6	2.90	.270	10.7
33	124.1	3.40	.306	11.1
32	124.3	3.20	.285	11.2
20	124.9	2.95	.279	10.6
22	125.1	3.17	.291	10.9
17	125.3	2.65	.317	8.4
25	125.7	2.90	.278	10.4
5	126.7	2.97	.268	11.1
18	127.0	2.67	.278	9.6
16	127.5	2.85	.278	10.3
34	127.7	3.35	.279	12.0
10	128.2	3.47	.306	11.3
29	129.7	3.40	.291	11.3
19	131.8	2.95	.303	9.7
15	132.3	3.05	.306	10.0
31	132.4	3.45	.298	11.6
9	132.7	2.92	.250	11.7
2	132.9	2.90	.276	10.5
6	133.0	3.12	.287	10.9
1	134.1	3.00	.275	10.8
Average of all	124.2	3.14	.290	10.8
Lowest five	111.3	3.29	.300	11.0
Next five	115.7	3.26	.296	11.0
Next five	121.0	3.19	.292	10.9
Next five	124.2	3.12	.286	10.9
Next five	126.4	2.81	.284	9.9
Next five	129.9	3.24	.297	10.9
Highest five	133.0	3.08	.277	11.1
Lowest ten	113.5	3.27	.298	11.0
Intermediate fifteen	123.9	3.04	.287	10.6
Highest ten	131.4	3.16	.287	11.0
Lowest twenty	118.0	3.21	.293	11.0
Highest twenty	128.4	3.06	.286	10.7

THAYER COUNTY.—Two series of samples similar to the above were taken in August, 1907, from adjacent prairie fields near Bruning, Thayer county. The first had been mown every year for hay so far as its history is known, whereas the other had been used only as a pasture. The data are given in Tables 5 and 7. Summaries are given in Tables 6 and 8 to show the effect of increasing the number of individual samples used in making a composite for analysis, and also to show the relation of the composition to the weight of the samples. In the case of only a few samples were humus determinations made.

In the first prairie the nitrogen varies from 0.227 to 0.268 per cent and in the second from 0.205 to 0.292 per cent, differences of 18 and 43 per cent respectively. By using composites of five individuals each, differences of 10 and 30 per cent respectively would have been obtained, and using composites of 10 individuals the differences would have fallen to 4 and 25 per cent respectively. Even with composites of 20 the differences, while less than 2 per cent in the first field, would have been 10 per cent in the second.

The decrease in nitrogen content with the increase of the weight of the cores is more marked with the samples from these prairies than with those from the one near Lincoln.

In the case of the second field there is a markedly higher content of nitrogen on the one side than on the other, altho so far as the history of the field is known the whole of it has been treated alike. This difference is more apt to be due to a difference in the texture of the soil in the two parts than to any difference in the history.

TABLE 5.—*Composition of individual samples from first prairie in Thayer county.*

Sample No.	Distance from preceding sample	Humus	Nitrogen	Weight of sample	Ratio of humus to nitrogen
		Per cent	*Per cent*	*Grams*	
1.......	....	....	.267	118.8	....
2	30 feet........	....	.243	132.3	....
3.......	30 feet........	....	.247	124.7	....
4.......	30 feet........	....	.257	129.9	....
5......	30 feet	3.68	.252	120.7	14.6
6	30 feet........	....	.249	124.8	....
7......	2 inches . ..	....	.254	124.8	....
8.......	2 inches	....	.255	129.8	....
9.......	2 inches	...	.257	112.4	....
10.......	2 inches	3.29	.265	112.4	12.5
11.......	30 feet........	....	.247	133.1	....
12	30 feet.... ...	....	.228	123.5	....
13.......	30 feet........	....	.255	110.4	....
14.......	30 feet........	....	.228	127.6	....
15.......	30 feet........	2.62	.230	126.6	11.4
16.......	30 feet........	....	.243	123.1	....
17.	2 inches	....	.254	109.0	....
18	2 inches	....	.242	120.3	....
19.......	2 inches	....	.254	111.6	...
20.......	2 inches . ..	3.86	.261	109.0	14.8
21.	30 feet.......	....	.213	136.3	....
22.......	30 feet........	....	.260	115.2	....
23.......	30 feet........	...	.228	135.8	....
24.......	30 feet........	....	.227	135.2	....
25.......	30 feet........	3.00	.233	122.9	12.9
26.......	30 feet........	....	.255	125.5	....
27.......	2 inches	....	.252	111.3	....
28.......	2 inches	....	.258	117.4	....
29.......	2 inches	....	.254	122.5	....
30.......	2 inches	2.95	.260	116.3	11.3
31.......	30 feet........	....	.257	123.3	....
32.......	30 feet........	....	.244	131.4	....
33	30 feet		.268	121.9	

TABLE 6.—*Summary of data in preceding table.*

	Weight of samples	Nitrogen
	Grams	*Per cent*
Average of all	122.4	0.248
First five, 30 feet apart	125.3	0.253
Second five, 2 inches apart	120.8	0.256
Third five, 30 feet apart	124.2	0.238
Fourth five, 2 inches apart	114.6	0.251
Fifth five, 30 feet apart	129.1	0.232
Sixth five, 2 inches apart	118.6	0.256
Last three, 30 feet apart	125.5	0.256
First ten	123.0	0.254
Second ten	119.4	0.244
Last thirteen	124.2	0.247
Lightest five	110.2	0.255
Next five	114.7	0.260
Next five	120.8	0.257
Next eight	124.1	0.248
Next five	129.1	0.243
Heaviest five	134.5	0.232
Lightest ten	112.4	0.257
Intermediate thirteen	129.8	0.250
Heaviest ten	131.8	0.238

TABLE 7.—*Composition of individual samples from second prairie in Thayer county.*

Sample No.	Distance from preceding sample	Humus	Nitrogen	Weight of 6-inch sample	Ratio of humus to nitrogen
		Per cent	*Per cent*	*Grams*	
1.	....	....	.238	147.	....
2.......	30 feet	....	.224	138.2	....
3.......	30 feet........	....	.211	146.9	....
4.......	2 inches.....	....	.217	136.5	....
5.	2 inches.....	....	.221	137.8	....
6.......	2 inches.....	....	.213	153.2	....
7.......	2 inches.....	2.30	.205	155.0	11.2
8.......	30 feet	....	.211	147.9	...
9.......	30 feet........	....	.221	149.6	....
10......	30 feet........	....	.216	150.0	....
11.......	30 feet........	....	.235	147.5	....
12.......	30 feet........	2.70	.233	138.2	11.1
13.......	30 feet........	....	.250	138.0	....
14.......	2 inches.....	....	.250	131.9	....
15.......	2 inches.....	....	.264	136.8	....
16......	2 inches.....	....	.264	129.8	..
17	2 inches.....	3.15	.265	140.8	11.9
18... ...	30 feet........	....	.234	148.2	....
19......	30 feet........	....	.235	139.2	....
20.......	30 feet........	....	.268	142.8	....
21.......	30 feet.......	....	.255	140.8	....
22.......	30 feet........	3.00	.257	144.9	11.7
23.......	30 feet........	....	.271	139.8	....
24.......	2 inches. ..	....	.282	128.6	....
25.......	2 inches.....	...	.272	135.1	....
26.......	2 inches.....	....	.272	132.7	....
27.......	2 inches.....	3.48	.292	133.8	11.9
28... ..	30 feet........	....	.278	138.5	....
29.......	30 feet........	...	.262	136.3	....
30.......	30 feet........	....	.264	130.2	...
31.......	30 feet........	....	.282	137.4	....
32.......	30 feet...	3.20	.272	137.9	11.8

TABLE 8.—*Summary of data in preceding table.*

	Weight of 6-inch sample	Nitrogen
	Grams	*Per cent*
Average of all	**140.4**	**0.248**
First two, 30 feet apart	**143.0**	**0.231**
Next five, 2 inches apart	**145.9**	**0.213**
Next five, 30 feet apart	**146.6**	**0.223**
Next five, 2 inches apart	**135.5**	**0.259**
Next five, 30 feet apart	**143.2**	**0.250**
Next five, 2 inches apart	**134.0**	**0.278**
Next five, 30 feet apart	**136.1**	**0.272**
First twelve	**145.7**	**0.220**
Next ten	**139.3**	**0.254**
Last ten	**135.0**	**0.275**
Lightest five	**130.6**	**0.266**
Next five	**135.7**	**0.261**
Next five	**137.9**	**0.252**
Next seven	**140.0**	**0 257**
Next five	**147.0**	**0.230**
Heaviest five	**151.2**	**0.218**
Lightest ten	**133.1**	**0.263**
Intermediate twelve	**139.1**	**0.254**
Heaviest ten	**149.1**	**0.224**

SAMPLES FROM PRAIRIES ON THE HIGH PLAINS

CHASE COUNTY.—In Table 9 are given the data on 10 individual samples from a prairie two miles east of Imperial, collected in September, 1907. The variation between extremes amounts to over 30 per cent of the lowest; but almost any combination of five, the heaviest, the lightest, the first or the last, gives an

TABLE 9.—*Composition of individual samples from virgin prairie near Imperial.*

Sample No.	Distance from preceding sample	Humus	Humus ash	Nitrogen	Weight of 6-inch sample
		Per cent	*Per cent*	*Per cent*	*Grams*
1		0.81	.28	.136	161.5
2	30 feet	0.76	.34	.110	170.8
3	30 feet	1.05	.43	.146	157.3
4	30 feet	0.70	.34	.131	168.8
5	30 feet	0.87	.46	.136	157.3
6	30 feet	1.06	.35	.155	148.8
7	30 feet	0.72	.33	.117	141.2
8	30 feet	0.93	.39	.131	156 3
9	30 feet	0.72	.33	.130	146.8
10	30 feet	0.99	.32	.143	152.3
	Average	0.86	.36	.134	156.0
Average of heaviest five		0.84	...	.132	163.1
Average of lightest five		0.88	...	.135	149.1
Average of first five		0.84	...	.132	163.1
Average of last five		0.88	...	.135	149.1

PERKINS COUNTY.—In November, 1907, about 90 individual samples were collected on various parts of the H O Ranch, north of Madrid. All but the extreme northern part of the ranch lies in Township 11 and Range 37. The samples were taken in seven series, the number in a series varying from five to twenty. The samples of each series were taken in a straight line at intervals of 30, 60, 100, or 200 feet. On the south part of the ranch, consisting of gently rolling "hard land," sets 1, 2, 3, and 7 were taken. In the case of all of these the prairie was covered with buffalo grass and all were taken within one mile of one another on what appeared to be uniform soil.

Nos. 1061 to 1065 were taken on the north half of Section 29 at intervals of 30 feet.

Nos. 1066 to 1080 were taken on the west half of Section 28 at intervals of 60 feet.

ranch is much more sandy than the south part and is commonly known as "sandy land," but not as "sand hill land."

Nos. 1101 to 1110 were taken on the southwest quarter of Section 5 at intervals of 75 feet. Buffalo grass was present where the samples of the first part of the series were taken.

Nos. 1111 to 1115 were taken on the northwest quarter of Section 5 at intervals of 100 feet. No buffalo grass was observed in this prairie.

Nos. 1117 to 1126 were taken at intervals of 200 feet from a field just north of Section 5 which had been plowed about 1890. cultivated for a few years, and later abandoned. It had since become covered with a thin stand of grasses.

TABLE 10.—*Composition of individual samples from prairies near Madrid, Perkins county.*

FIRST SERIES

Soil No.	Nitrogen	Humus	Humus ash
	Per cent	*Per cent*	*Per cent*
1061	.120	.67	.36
1062	.130	.74	.38
1063	.121	.76	.45
1064	.100	.62	.36
1065	.124	.63	.45
Average	.119	.68	...
SECOND SERIES			
1066	.096	.68	.40
1067	.098	.61	.35
1068	.124	.61	.44
1069	.099	.70	.36
1070	.125	.79	.38
1071	.171	1.30	.50
1072	.179	1.34	.56
1073	.228	1.57	.41
1074	.201	1.26	.51
1075	.209	1.08	.39
1076	.171	1.08	.50
1077	.138	.99	.48
1078	.148	1.00	.57
1079	.135	.77	.43
1080	.127	.75	.38
Average	.150	.97	...
Average for slope to east	.140	.95	...

TABLE 10.—*Composition of individual samples from prairies near Madrid, Perkins county—Continued.*

THIRD SERIES

Soil No.	Nitrogen	Humus	Humus ash
	Per cent	*Per cent*	*Per cent*
1081	.158	1.12	.56
1082	.124	.67	.49
1083	.103	.64	.47
1084	.124	.95	.33
1085	.199	1.81	.63
1086	.164	1.48	.54
1087	.149	1.36	.74
1088	.160	1.34	.58
1089	.172	1.35	.58
1090	.110	.85	.52
1091	.114	.96	.32
1092	.134	.78	.39
1093	.123	.76	.54
1094	.124	.85	.34
1095	.118	1.14	...
1096	.142	1.26	.76
1097	.151	1.03	.52
1098	.103	.70	.42
1099	.094	.73	.37
1100	.094	.73	.56
Average	.133	1.02	...
FOURTH SERIES			
1101	.131	1.02	.38
1102	.141	.98	.39
1103	.179	1.59	.56
1104	.157	1.42	.46
1105	.167	1.28	.41
1106	.091	.95	.41
1107	.082	.80	...
1108	.087	.86	.29
1109	.097	.64	.42
1110	.101	.70	.36
Average	.122	.94	.
FIFTH SERIES			
1111	.079	.55	.42
1112	.092	...	...
1113	.039	...	...
1114	.052	.48	.46
1115	.071	...	...
Average	.067	...	. .

TABLE 10.—*Composition of individual samples from prairies near Madrid, Perkins county—Concluded.*

SIXTH SERIES

Soil No.	Nitrogen	Humus	Humus ash
	Per cent	*Per cent*	*Per cent*
1117	.082	.70	...
1118	.112	.95	.58
1119	.109	.78	.48
1120	.106	.98	.48
1121	.097	.75	...
1122	.099	.75	.55
1123	.102	.75	...
1124	.104	.75	.55
1125	.093	.60	.36
1126	.089	.58	.42
Average	.099	.76	...

SEVENTH SERIES

Soil No.	Nitrogen	Humus	Humus ash
1128	.144	1.09	.60
1129	.157	1.10	...
1130	.163	.92	.47
1131	.137	1.07	.43
1132	.151	1.16	.46
1133	.151	1.01	.52
1134	.158	1.01	...
1135	.134	.93	.50
1136	.153	1.33	.54
1137	.134	1.00	.65
1138	.131	.86	.78
1139	.118	.81	.46
1140	.106	.81	.71
1141	.147	1.15	.80
1142	.106	.80	.62
1143	.112	1.10	.58
1144	.147	1.18	.55
1145	.118	.85	.54
1146	.118	.87	.57
1147	.112	.67	.44
Average	.135	.99	...

TABLE 11.—*Summary of data in Table 10.*

	Nitrogen	Humus
	Per cent	*Per cent*
First series—5	.119	.68
Second series—15	.150	.97
Third series—20	.133	1.02
Fourth series—10	.122	.94
Fifth series—5	.067	...
Sixth series—10	.099	.76
Seventh series—20	.135	.99
SERIES ARRANGED IN ORDER OF NITROGEN CONTENT.		
Second series	.150	.97
Seventh series	.135	.99
Third series	.133	1.02
Fourth series	.122	.94
First series	.119	.68
Sixth series	.099	.76
Fifth series	.067	...

In the second series the first seven samples were from the west side of a depression and the last four from the east side. The other four were from the bottom of the depression. It will be seen that the nitrogen and humus are distinctly higher in the samples from the bottom of the depression than in those from either slope. The samples from the hard land show a much higher nitrogen content than those from the sandy land. Likewise the buffalo grass tracts show a higher nitrogen content than the sand grass tracts. Both the presence of the buffalo grass and the high nitrogen content are to be regarded as due to the heavier texture of the soil in the case of the hard land.

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2. Alway, Files, and Pinckney: The determination of humus, Bulletin 115, Nebraska Experiment Station, pages 13 and 15 (1910).
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ON THE SAMPLING OF CULTIVATED SOILS

BY F. J. ALWAY AND E. K. FILES

The methods of analysis used were similar to those described on page 36 of this Report. In taking samples to a depth of six inches the sampler described above was used.

In August, 1907, 12 individual samples were taken in a field that had been under cultivation for 40 years and had been sown to alfalfa in the preceding spring. The field lies near some large stock feeding barns and had been heavily manured for many years, it having been used to produce forage. The history of the field and the conditions under which the alfalfa started have been described for Field I on page 9 of the Twenty-Third Annual Report of the Nebraska Experiment Station. The data on these samples are given in Table 1.

TABLE 1.—*Composition of individual soil samples taken from a field of young alfalfa.*

Sample No.	Condition of alfalfa	Humus	Nitrogen
		Per cent	*Per cent*
1	Better than the average	2.90	.227
2	Less vigorous than at 1	2.55	.207
3	Less vigorous than at 1	2.65	.213
4	Like that at 1	2.45	.213
5	Very vigorous	2.70	.238
6	Very yellow and stunted	3.00	.241
7	Very yellow and stunted	2.85	.238
8	Better than at 7	2.60	.221
9	Better than at 8	2.60	.220
10	Very vigorous	2.30	.220
11	Very vigorous	2.45	.206
12	Very vigorous	2.55	.210
Average		2 62	.221

portion of the field. At this time the alfalfa had made two seasons' growth. The method of sampling was as follows: Two stakes were placed 4 rods apart and with these as centers two circles, each 10 feet in diameter, were described. In each circle an equilateral triangle was inscribed and from the six points of contact of the triangles with the circles samples were taken by means of the six-inch sampler, previously described. Then both triangles were rotated thru a distance of one foot and another set of composite samples similarly taken, this being repeated until 10 composites in all had been taken. Thus from each of the areas, four rods apart, 30 samples had been taken in a circle at intervals of one foot.

On the following day a similar set of 10 composite samples was taken from a field which had been in brome grass for about 15 years and previous to that time had been in cultivation about 20 years. The data for the fields are given in Table 2.

TABLE 2.—*Nitrogen content and weight of different samples from the same field.*

Sample No.	Nitrogen		Average weight of each sample dried at 110° C.	
	Alfalfa field	Brome grass field	Alfalfa field	Brome grass field
	Per cent	*Per cent*	*Grams*	*Grams*
1	.202	.231	119.1	94.8
2	.207	.241	106.5	99.5
3	.202	.226	116.3	98.1
4	.205	.226	109.5	93.6
5	.216	.231	121.0	87.0
6	.205	.235	106.3	87.7
7	.206	.232	115.3	89.6
8	.202	.229	108.3	89.0
9	.200	.229	115.7	92.5
10	.199	.235	112.6	95.1
Average	.204	.231	113.1	92.7
Highest	.216	.241	119.1	99.5
Lowest	.199	.226	106.3	87.0

It will be seen that the extremes of nitrogen were .216 and .199 in the alfalfa field and .241 and .226 in the brome grass field. Nine of the samples from the alfalfa field gave concordant results, but one gave .009 per cent more nitrogen than the next highest. In the brome grass field there was a greater variation among the ten composites and in some cases no improvement in accuracy would have been effected by using twelve individuals. instead of six, as a composite. In general, however, the accuracy would have been increased by every increase in the number of samples used in making the composite.

There was a similar variation in the average weight of the cores. The samples from the brome grass field were in all cases decidedly lighter than those from the alfalfa field, the lightest set from the alfalfa field being decidedly heavier than the heaviest set from the brome grass field. In order to have gotten the same weight of soil from the brome grass field it would have been necessary to take the samples in this to a depth of seven and one-third inches against six inches in the alfalfa field. The effect on the nitrogen content of the samples that would have been caused by this is shown in Table 3. There would have been practically no effect. Hence the difference in the weights of the samples was without appreciable influence upon the results.

In order to determine the effect of sampling to different depths, due to the soil being loose in some cases and compact in others, two sets of 12 samples each were taken to a depth of one foot from near the above described circles in the same two fields and these were divided into inch sections. The resulting sections were combined to form composite samples for each inch. The data on these are given in Table 3. In the second part of the table there are shown the percentages which would have been obtained had the samples been taken to 2, 3, 4, etc., inches. In the alfalfa field every increase in depth by one inch would have lowered the nitrogen content more or less, but in the brome grass field practically no difference would have resulted from taking a sample to a depth of 4, 5, 7, or 8 inches instead of 6. Below the eighth inch there was a steady decline in nitrogen. Even in the alfalfa field the effect of having taken the sample to a depth of five or of eight inches instead of six would have been slight. Hence, we are safe in concluding that no special precautions would need to be exercised in sampling these two fields so as to get samples of the same weight, but that the precaution that should be taken is that of increasing the number of individual samples used in making the composites.

TABLE 3.—*Nitrogen content or different inch sections of the surface foot of soils in two long cultivated fields.*

Depth of section	Alfalfa field	Brome grass field
	Per cent	*Per cent*
First inch	.213	.222
Second inch	.212	.230
Third inch	.198	.231
Fourth inch	.192	.223
Fifth inch	.194	.226
Sixth inch	.192	.224
Seventh inch	.190	.222
Eighth inch	.185	.222
Ninth inch	.180	.209
Tenth inch	.171	.196
Eleventh inch	.159	.196
Twelfth inch	.151	.177
Average	.186	.216
First inch	.213	.222
Average to two inches	.212	.226
Average to three inches	.208	.228
Average to four inches	.204	.226
Average to five inches	.202	.226
Average to six inches	.200	.226
Average to seven inches	.199	.225
Average to eight inches	.197	.225
Average to nine inches	.195	.223
Average to ten inches	.193	.221
Average to eleven inches	.190	.218
Average to twelve inches	.186	.216

SOME NOTES ON ALFALFA AND CLOVER RESIDUES AS SOURCES OF SOIL NITROGEN

BY F. J. ALWAY AND E. S. BISHOP

It has already been pointed out in publications of this Station[1] that the problem of maintaining the fertility of the loess soils of eastern Nebraska is, in so far as the chemical composition is concerned, essentially that of maintaining the supply of total organic matter, which includes both humus and nitrogen. The problem with the loess soils of western Nebraska also, in so far as the chemical composition is concerned, is the same. The only two sources of nitrogen that are at present to be recommended to Nebraska farmers are barnyard manure and leguminous crops. Of course all crop residues, such as straw, cornstalks, etc., should be returned to the soil instead of being burned, as is, at present, too commonly the case. Whether the hay should be fed and the part of the nitrogen in the form of manure returned to the fields, or whether the entire leguminous crop should, from time to time, be plowed under, is a disputed question. It will be much harder to persuade a farmer to use a rotation including a leguminous crop to be plowed under than one where he gathers the hay and plows under only the plant residues, including fallen leaves, stubble, etc. In both cases the roots from the legumes are left in the soil. It is claimed by some that where clover is grown and the aerial portion of the plants removed, the soil does not become any richer in nitrogen. Thus Hopkins[2] states, "When grown on soil of fair productive capacity, the roots and stubble of the clover plant contain no more nitrogen than the soil has furnished to the plant." Whether this is the case in Nebraska we do not have data from which to decide. For practical purposes it really is not a very important question. The amount of residues that the farmer involuntarily leaves on a field is very large. These residues steadily become incorporated in the surface soil even tho no cultivation takes place. The manner of this incorporation is discussed elsewhere in this Report. Further, there will usually be at least a very considerable portion of the hay fed on the same farm where it is produced, the manure from this being returned to the fields and thus still further increasing the nitrogen supply resulting from the growth of legumes on the farm. Provided only that the farmer produce a large enough acreage of legumes and make the best use of all the barnyard manure produced on his farm, it is probable that he need give himself no concern regarding the theoretical question alluded to above. At all times he should remember that the greatest losses of nitrogen are due to erosion by wind and water and that it is simpler to check this erosion than it is to replace the nitrogen lost thereby.

In the absence of any extended study of this subject in Nebraska, all local data bearing upon it become of interest and for this reason the following notes are published at this time.

AT THE EXPERIMENT STATION FARM, LINCOLN.—Early in the spring of 1910 a field on the Experiment Station Farm was sown to red clover, no nurse crop being used. A very thick and uniform stand was secured and the plants made a most luxuriant growth. The field was mown about September 1 and the hay removed. August had been a remarkably wet month, 14.41 inches having fallen at the Experiment Station, and of this 8.60 inches fell during one night, that of August 29 to 30. The aftergrowth was allowed to stand without pasturing and plowed under during the latter part of October. On the 21st of that month, when the plowing had been nearly finished, we collected to a depth of one foot and placed on a large sheet of paper. The roots and above-ground portions of the plants were carefully removed, counted, and washed free of soil. After the roots had been separated from the aerial portions, the two parts were dried separately at 110° C., weighed, and analyzed. On the one square foot there were 23 plants and on the other two 53 and 59, respectively. The roots from the 135 plants weighed, after drying, 58.7 grams and had a nitrogen content of 2.17 per cent. The aerial portions, after drying, weighed 124.2 grams and had a nitrogen content of 3.42 per cent. Calculated on this basis the amount of roots and aerial portions per acre would be 1,882 pounds and 3,976 pounds, respectively. The roots would have contained 41 pounds of nitrogen per acre and the tops 136 pounds, making 177 pounds in all. The weight of the air-dried aerial portions was far greater than could have been gathered in the form of hay had the field been mown in the latter part of October, for the reason that a great many stems and leaves were lying dead on the surface and there would have been a comparatively dense mat of stubble left by the mower.

On November 12 of the same year the roots alone were gathered from three typical cubic foot sections in a young alfalfa field just east of the factory of the Nebraska Silo Co. The plants had very little top left, so little that it was not representative of the conditions in a hay field, and for this reason the tops were rejected, the roots only being used for analysis. The field had been heavily manured for many years and had been sown to alfalfa in the autumn of 1909, a large amount of seed being used and a very thick stand of plants resulting. On the three areas where the samples were taken this was found to vary from 42 to 52 plants per square foot. The data are given in Table 1. Calculated from the data in the table the weight of the roots was 3,650 pounds and the nitrogen content of the roots to a depth of one foot would amount to 73 pounds per acre, nearly twice as much as that contained in the roots in the clover field described above.

TABLE 1.—*Alfalfa plants on one square foot.*

Sample No.	Number of plants per square foot	Weight dried at 110° C.	Nitrogen	Weight of nitrogen
		Grams	*Per cent*	*Grams*
1...........	42	39.9	2.12	0.86
2...........	52	37.8	1.97	0.74
3...........	42	34.9	1.92	0.67
Average	45	37.5	2.00	0.76

In order to secure some data as to the amount of nitrogen contained in the residues left on an alfalfa field, samples were collected from three typical areas of one square yard each in different parts of the field described as "Field I" on page 10 of the Twenty-third Annual Report of the Nebraska Experiment Station. This field had been in alfalfa for five years, not being pastured at all. The last cutting of hay in 1910 had been made very late in October and very little after-growth had appeared between the time of cutting and the time of sampling, November 12. The living plants were cut off even with the surface and all dead stems, leaves, etc., lying on the ground were carefully gathered. The whole of this organic matter, consisting of leaves, stems, and partly decayed residues, was dried, weighed, and analyzed. The data are given in Table 2. This may be regarded as strictly representative of the ordinary alfalfa fields in which there is a good stand of plants. Calculated from the average weight of the three samples the weight of alfalfa residues per acre would amount to 5,478 pounds with a nitrogen content of 126 pounds.

TABLE 2.—*Alfalfa residues on one square yard.*

Sample No.	Weight of residues dried at 110° C.	Nitrogen	Weight of nitrogen
	Grams	*Per cent*	*Grams*
1................	406	2.45	9.96
2................	435	2.62	11.40
3................	768	1.84	14.13
Average ...	536	2.30	11.83

AT THE FARM OF HON. GEORGE COUPLAND NEAR ELGIN.—In the latter part of September, 1910, the roots were collected from the surface foot of a field of Mammoth red clover which had been sown with winter wheat the year before. On the same day the roots of alfalfa plants were similarly collected from a field sown in 1908.

TABLE 3.—*Alfalfa and clover roots from one cubic foot.*

	Weight of roots dried at 110° C.	Nitrogen	Nitrogen per acre
	Grams	*Per cent*	*Pounds*
Clover field	19.4	1.69	32
Alfalfa field....	40.8	1.91	76

At the time the above samples were collected two pits had been dug to permit of the taking of samples for bacteriological studies,[3] and, from the walls of these, samples were taken for nitrogen determinations. The pits were four feet long, two and one-half feet wide, and twelve feet deep, with vertical walls. The one was within a cornfield which had been in continuous cultivation for 28 years without the application of any manure or fertilizers and on which no leguminous crops had been grown. The other pit was in a field differing from that just mentioned in that it had during the preceding 8 years been in alfalfa, all the crops being removed as hay and no fertilizers applied. The latter pit was about 60 feet within the edge of the alfalfa field and had accordingly, been surrounded on all sides by a good stand of alfalfa plants. During the preceding winter the plants in many parts of the field had died out. Several counts were made where diameter. On account of the very dry condition of the soil at the time, it was not found feasible to remove the roots intact. Of some twenty roots which we attempted to remove, only eleven were secured intact to a depth of three feet and only one to a depth of four, this one being secured intact to a depth of a little over ten feet. It is shown in the accompanying photograph. The eleven 3-foot roots were cut up into foot sections, dried and analyzed. The 10-foot root was treated similarly. The data are given in Table 4. The alfalfa roots in the subsoil were surrounded by a black, humus-like layer.

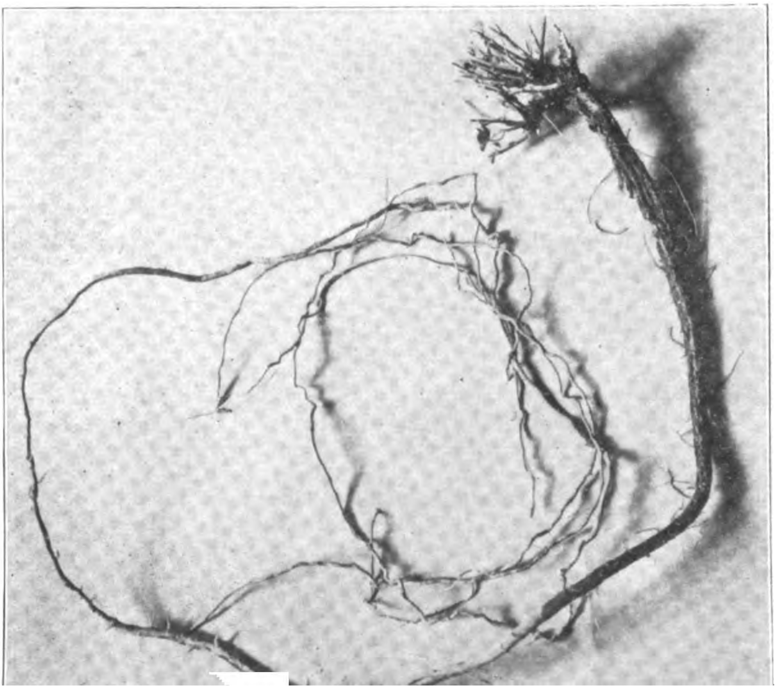

TABLE 4.—*Weight and nitrogen content of foot sections of roots of alfalfa plants eight years old.*

Depth	Ten-foot root from one plant		Three-foot roots from eleven plants	
	Dry weight	Nitrogen	Dry weight	Nitrogen
Feet	*Grams*	*Per cent*	*Grams*	*Per cent*
1...	7.06	1.89	73.20	2.07
2..........	2.57	2.10	21.88	1.84
3.........	1.29	1.87	11.58	1.82
4..........	.85	....	.....	....
5..........	.43	....	.....	....
6.........	.26	....	.....	....
7..........	.27	....	.....	....
8..........	.22	....	.....	....
9..........	.17	....	.....	....
10..........	.18	....	.. .	....

From the data in the above table an estimate has been made of the amount of nitrogen in the form of alfalfa roots contained in the various acre-foot sections, it being assumed that the roots analyzed were average specimens, that there had been a stand of eight plants to the square foot, and that the weight of an acre-foot of soil is 3,500,000 pounds.

TABLE 5.—*Organic matter and nitrogen contained in roots of alfalfa plants in a field which had been in alfalfa eight years.*

Depth	Weight of organic matter			Nitrogen		
	Per plant	Per cubic foot	Per acre-foot	In dry roots	Per acre foot	In soil layer in the form of alfalfa roots
Feet	*Grams*	*Grams*	*Pounds*	*Per cent*	*Pounds*	*Per cent*
1....	6.60	52.8	5,069	2.07	104.9	0.00300
2....	2 00	16.0	1,536	1.84	28.3	0.00080
3....	1.05	8.4	806	1.82	14.7	0.00040
4....	.85	6.8	653	1.51	9.9	0.00030
5 ...	.43	3.4	330	1.18	3.9	0.00010
6....	.26	2.1	200	.99	2.0	0.00006
7 ...	·27	2.2	207	1.12	2.3	0.00007
8 ...	22	1.8	169	.94	1.6	0.00004
9....	.17	1 4	135	1.12	1.5	0.00004
10....	.18	1.4	135	1.00	1.5	0.00004

From both pits the samples of soil, except for the first foot, were secured by first removing a layer six inches in thickness from the face of the wall and then taking half a cubic foot of soil from behind this. This large sample was thoroly mixed and a five-pound sample taken for analysis. Alfalfa roots were removed before grinding, for analysis. For the samples of the surface foot of soil from each of the two fields twelve borings from various parts of the fields were combined as composites. The undecayed alfalfa roots were not included in the sample of soil from the surface foot of the alfalfa field. The data are given in Table 6.

TABLE 6.—*Nitrogen in the soil of the two fields at different levels.*

Depth	Cornfield		Alfalfa field	
	Per cent	Pounds per acre-foot	Per cent	Pounds per acre-foot
Feet				
1 ...	.157	5,495	.166	5,810
2....	.107	3,745	.075	2,625
3....	.074	2,590	.055	1,925
4....	.050	1,050	.040	1,400
5....	.024	940	.054	1,890
6....	.021	735	.036	1,260
7....	.027	945	.025	875
8....	.017	595	.022	770
9....	.022	770	.020	700
10....	.019	665	.016	560
11....	.019	665	.021	735
12....	.022	770	.022	770

No marked difference is to be seen between the amounts of nitrogen in the soils of the two fields as represented by the samples analyzed. The relative nitrogen content at any level ap-

TABLE 7.—*Weight of nitrogen per acre-foot in soil and in alfalfa roots at different levels.*

Depth	Cornfield	Alfalfa field	
	In the soil	In the soil	In the alfalfa roots
Feet	*Pounds*	*Pounds*	*Pounds*
1	5,495	5,810	105
2	3,745	2,625	28
3	2,590	1,925	15
4	1,050	1,400	10
5	940	1,890	4
6	735	1,260	2
7	945	875	2
8	595	770	2
9	770	700	1
10	665	560	1

On the alfalfa roots as exposed on the pit walls, but few nodules were found within the first eight inches, but at a greater depth they were numerous, many large clusters being found in the second and third feet and one very large cluster at a depth of four feet. All of these deeply located clusters had apparently formed in old, vertical fissures formed by the shrinkage of the soil.

The absence of nodules on the alfalfa roots near the surface is no evidence of the lack of inoculation when the observations are made during a protracted drouth. In the latter part of August, 1911, we made many attempts to find nodules on alfalfa roots in the fields near the Experiment Station Farm, fields which we had inspected at frequent intervals for several years

At the H O Ranch, Perkins County.—On November 12, 1907, an excavation to a depth of 7 feet was made in a field of dry land alfalfa sown in 1905. All the living plants had roots extending to a depth of 4½ to 5 feet and about one-third of them extended below the bottom of the excavation. The largest roots found at that depth were 2 mm. in diameter. Counts were made of the plants per square yard in three typical places in each of three fields sown two years before. The averages were 16, 14, and 10 per square yard. A large number of plants were dug up and on about three-fourths of these nodules were found. The ground was very dry and it is not improbable that the nodules on the other plants had been torn off on removing the adherent soil.

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A COOPERATIVE INVESTIGATION ON THE LOSSES OF NITROGEN, ORGANIC MATTER, AND HUMUS FROM SOME NEBRASKA SOILS

BY F. J. ALWAY AND E. S. BISHOP

This Experiment Station very frequently receives samples of soil from farmers and other land owners in the state, with the request that these be analyzed and the analyses reported to the sender. There is no provision at this Experiment Station for the expenses connected with such work, the funds used for the maintenance of the experimental work of the Department of Agricultural Chemistry being derived almost entirely from appropriations made by the Federal Government for specific investigations. The actual cost of a complete soil analysis is about $25, the exact amount depending upon the skill of the analyst, upon the rate of remuneration he receives, and upon various other varying factors, and the results are likely to be of *no value at all* unless the samples be taken properly. In practically no cases are the samples so taken. Usually the sender has only scraped off from the surface a few ounces of soil, but occasionally he has also taken from below the furrow slice, at a depth of 6 to 10 inches, a very small sample, this usually being secured by digging a shallow hole in a single place. When he is informed that the analysis of such samples would be useless and is sent specific directions for sampling, seldom is he willing to go to the trouble required to properly take the sample, even when the offer of an analysis without charge is made.

Occasionally the investigation under way is of such a nature that the analysis of properly taken samples sent in by farmers ing to directions. As an illustration we might cite the case of an investigation of soils in a well-settled community in western Nebraska. About 10 sets of samples, each consisting of one of surface soil and one of subsoil, were desired in connection with an investigation being carried on, and it was necessary either to send an assistant of the Experiment Station to take the samples, or to ask some of the farmers in the vicinity to take them and send them in. As several letters had been received asking for information regarding the advisability of the use of commercial fertilizers on these soils, and as a number of samples taken as above described had been sent in for analysis, it was thought that the farmers might be enough interested to take the samples in order that they might have the analyses without incurring any expense. Accordingly, an offer was made to analyze, without charge, ten such sets of samples, the Experiment Station sending sample sacks and paying the transportation charges. Not a single set of samples has yet been received.

In 1909 an offer to make free soil analyses for graduates and students of the School of Agriculture was rendered possible by the need of a large number of samples of surface soil from various parts of the State. Accordingly, in the issue of "Agriculture" for September, 1909, the following offer was made:

> "Analyses showing the nitrogen, organic matter, and humus will be made without charge for all graduates and students of the School of Agriculture who take the samples according to directions and who deliver them to the Experiment Station not later than January 30, 1910. All those wishing to take advantage of this offer should send a postal card or letter to the chemist so that he may send them directions and soil sacks. The

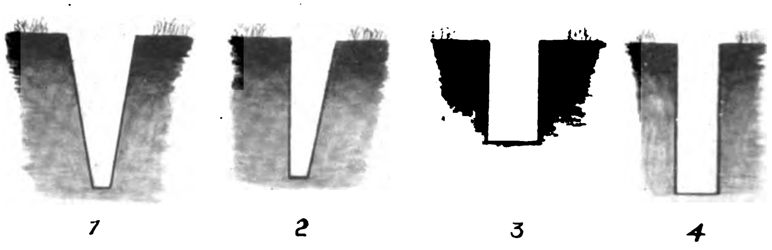
of the graduates and students but of these only 15 delivered samples. The results of the analyses are given in the table below. The names of the senders are not given, they having been informed of the series number of their samples.

The directions sent to each man are given in the following paragraphs:

DIRECTIONS FOR TAKING SAMPLES OF SURFACE SOIL.

"If the samples are not taken with full attention to directions the results obtained from the analyses will have little or no significance.

"For the sample of long cultivated soil select as level a field as you have which has not been manured and of which you know the approximate date of breaking. If all your fields have been manured or if you do not know their history it would be well to get the samples from some neighbor's field to which no manure has been applied and of which the history is known.



"The sample of virgin soil should be taken from the nearest remaining prairie whether it has been used as pasture or as hay land. If the prairie is bottom land the cultivated field should

Then take the sample as described above. In this case it is extremely important that the samples be taken to a depth of just 6 inches and that the walls be vertical, because the amounts of nitrogen, humus, and organic matter all decrease rapidly from the surface downward. Thus samples from holes like 1, 2, and 3 will be richer than those from holes like 4."

The nitrogen percentages were determined and from these the total organic matter and the humus were calculated, there being in the case of the surface soil a practically constant relationship between the amount of nitrogen and the amount of the other two constituents, altho the ratios of the nitrogen to the organic matter and to the humus in the cultivated fields are different from those in the case of the virgin prairies. On none of the fields, to the knowledge of the owners, had leguminous crops been grown and on none except numbers 7, 12, and 14 had barnyard manure been applied, and on each of these only once.

In all cases, as was to be expected, there had been a decline in nitrogen, organic matter, and humus. On account of the small number of cases in which the full history of the cultivated fields was known by the senders it is not possible from the above data to indicate the relationship between the losses of nitrogen and the length of time the fields had been under cultivation.

A detailed discussion of the changes in the chemical composition of the loess soils of Nebraska which have been caused by cultivation has been given in Bulletin 111 of this Experiment Station.

County	Number of years in cultivation	Nitrogen			Total organic matter			Humus		
		Prairie	Cultivated field	Loss	Prairie	Cultivated field	Loss	Prairie	Cultivated field	Loss
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Colfax	13	.255	.226	.029	5.35	4.25	1.10	2.45	1.98	.47
Buffalo	..	.238	.197	.041	4.78	3.51	1.27	2.02	1.73	.29
Hamilton	..	.174	.152	.022	3.50	2.70	.80	1.46	1.34	.12
Wheeler	..	.340	.278	.062	7.14	5.23	1.91	3.26	2.65	.61
Gage	..	.235	.217	.018	4.60	3.99	.61	2.68	2.43	.25
Sarpy	56	.252	.171	.081	4.94	3.75	1.19	2.87	1.91	.96
Dodge	..	.315	.247	.068	6.61	4.64	1.97	2.60	2.17	.43
Antelope	20	.210	.198	.012	4.41	3.72	.69	2.02	1.74	.28
Richardson	40	.210	.183	.027	4.11	3.37	.74	2.39	2.05	.34
Thayer	..	.219	.169	.050	4.29	3.10	1.19	2.50	1.89	.61
Polk	.	.284	.231	.053	5.56	4.25	1.31	3.24	2.58	.66
Burt	32	.302	.212	.090	6.34	3.98	2.36	2.90	1.86	1.04
Polk	..	.210	.186	.024	4.12	3.42	.70	2.39	2.08	.31
Dodge	35	.306	.200	.106	6.15	3.56	2.59	2.57	1.76	.81
York	..	.257	.198	.059	5.02	3.64	1.38	2.93	2.22	.71

ON THE DETERMINATION OF SOIL MOISTURE

By R. S. Trumbull

The following data indicate the degree of accuracy which may conveniently be attained when one has occasion to make moisture determinations at places far from any laboratory and where he is provided with no apparatus except a small balance, a set of weights, and some tin cans, such as empty baking powder or cocoa cans.

In November, 1907, a large number of samples of soil were taken for moisture determinations at the H O Ranch in Perkins county, Nebraska. All samples, as they were taken in the field, were placed in quart fruit jars, which were at once tightly covered and in the evening taken to the ranch house. The contents of each jar were thoroly mixed and samples of 100 grams weighed out in duplicate and placed in small weighed cotton sacks. These were later shipped by express to the Experiment Station and there dried at 110° C. in an electric oven thru which a rapid current of air was kept passing. Wishing some immediate information as to the moisture in different fields, samples from five fields were dried in the oven of the ranch cook-stove. The results agreed so well with those obtained at the laboratory that they are given below.

After placing the weighed samples in the cotton sacks, similar samples were weighed out into small tin cans, which were placed in the oven of the cook-stove in the evening and removed the next morning. The following evening the samples were dried for a few hours, then covered tightly and allowed to cool during the night, being weighed the following morning. This drying was continued until no further loss in weight was caused by an evening's drying. The agreement between the determinations made in the range oven and those made in the laboratory as above de scribed is shown in Table 1, while the agreement of duplicate determinations made in the cook-stove oven are shown in Table 2.

The results obtained by using the cook-stove oven are, accordingly, entirely satisfactory for all practical purposes. The greatest source of error evidently lies in the absorption of hygroscopic moisture from the air during the cooling. If the drying be thoro and the can be at once covered with a tight-fitting cover any error from this source can be avoided.

TABLE 1.—*Moisture content as determined in the oven of a cook stove, compared with that found by drying in a laboratory oven.*

Depth	Laboratory oven	Cook-stove oven	Difference
		FIRST FIELD.	
Feet	*Per cent*	*Per cent*	*Per cent*
1	11.5	11.0	.5
2	11.1	9.9	—1.2
3	9.5	9.8	.3
4	10.0	9.9	.1
5	8.8	9.3	.5
6	9.1	9.2	.1
7	10.2	9.7	— .5
Average	10.0	9.8	— .2
		SECOND FIELD.	
1	12.8	10.5	—2.3
2	9.1	9.3	.2
3	7.2	6.5	— .7
4	5.1	4.8	— .3
5	5.5	4.8	— .7
6	7.5	7.7	.2
7	11.3	11.1	— .2
Average	8.3	7.8	— .5
		THIRD FIELD.	
1	9.5	10.0	.5
2	12.4	13.4	1.0
3	14.8	14.6	— .2
4	20.7	20.8	.1
5	14.4	13.5	— .9
6	10.7	10.2	— .5
7	10.1	9.0	—1.1
8	12.5	12.0	— .5
9	11.2	10.9	— .3
Average	12.9	12.7	— .2

Table 1.—*Moisture content as determined in the oven of a cook-stove, compared with that found by drying in a laboratory oven—Concluded.*

FOURTH FIELD.

Depth	Laboratory oven	Cook-stove oven	Difference
Feet	*Per cent*	*Per cent*	*Per cent*
1	10.6	10.2	— .4
2	14.3	14.3	.0
3	15.2	15.6	.4
4	14.7	15.5	.8
5	12.7	12.0	— .7
6	16.0	15.8	— .2
7	13.6	13.6	.0
8	12.3	13.0	.7
9	12.2	12.7	.5
Average	13.5	13.6	.1

Table 2.—*Concordance of duplicate moisture determinations made in cook-stove oven, using samples from a summer-fallow.*

Depth	1	2	Average	Difference
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	18.4	18.1	18.3	.3
2	22.1	22.2	22.1	.1
3	20.0	20.2	20.1	.2
4	16.8	17.5	17.1	.7
5	17.1	16.8	17.0	.3
6	16.3	16.0	16.1	.3
7	10.0	10.2	10.1	.2

THE DETERMINATION OF TOTAL MANGANESE IN SOILS

By Ross A. Gortner and Clayton O. Rost

INTRODUCTION

It is a well-known fact that the gravimetric estimation of small quantities of manganese, such as occur in rocks or soils, is highly inaccurate even when great care is used. The inaccuracy may be caused by a number of factors, including incompleteness of separation from the iron and aluminum, incomplete precipitation, and contamination of the precipitate by other substances. These errors, because of the small amounts of manganese present, cannot be depended upon to counterbalance one another.[1] The usual method which is now employed is to determine the manganese colorimetrically after oxidation to permanganic acid. Various means of effecting this oxidation have been employed. The oldest method is the oxidation of the manganese in nitric acid solution by the addition of lead peroxide.[2] This material proved unsatisfactory owing to the necessity for the removal of the excess of the lead peroxide, which settles very slowly.

Acting on the suggestion of Marshall,[3] Walters[4] substituted ammonium persulphate for the lead peroxide. All of Walters' determinations were made on either steel, pig iron, or blast furnace cinders. This method was later adopted by Hillebrand[1] and Washington[5] for the determination of total manganese in rocks.

and oxidizing the manganese to permanganic acid by the addition of ammonium persulphate. The permanganic acid solution is then diluted to a known volume and the color read against a solution of known strength in a colorimeter.

In applying this method to Nebraska soils, following the detailed directions of Washington[5] we have found that we could not obtain concordant results on duplicate determinations, the variation between duplicates being sometimes as much as 200 per cent. Brinton[6] has already noted that in some iron ores the treatment with sulphuric and hydrofluoric acids does not give complete extraction of the manganese, and we have found that this is the case with all of the soils which we have investigated. In most of these soils, three, and in some cases four, extractions with hydrofluoric and sulphuric acids were necessary before all of the manganese was obtained in solution. Inasmuch as each extraction requires nearly three hours, it will be seen that to accurately determine manganese in soils by this method is a very tedious operation. We have, therefore, endeavored to devise a method which is much more rapid, more accurate, and which requires less attention, and eliminates all fumes of hydrofluoric acid or sulphur trioxide. The smaller amount of platinum required in the process is also a decided advantage.

As an oxidizer we have used sodium bismuthate instead of ammonium persulphate, inasmuch as it gives a better oxidation, always giving the true permanganate color, while the persulphate oxidation often produces a reddish tint that is difficult to read accurately. Blair[7] and Brinton[6] seemed to recognize the superiority of the "bismuthate" oxidation by stating that "for samples containing not over 2 per cent of manganese the bismuthate is the most accurate method known." Walters[4] states that the persulphate oxidation does not always progress smoothly, for when the salt is dry "the reaction is very incomplete and irregular and not to be depended on," a fact that is not mentioned in the description of the method by Hillebrand or Washington. By moistening the persulphate much more concordant results are obtained, but we have found that the bismuthate is much more reliable than the persulphate. In some instances we were unable to oxidize all of the manganese by means of ammonium per sulphate, but when these same solutions were reduced with sulphurous acid and reoxidized with bismuthate the correct percentage of manganese was obtained. The bismuthate method has the added advantage over the persulphate in that it is not necessary to add silver nitrate to catalyze the reaction.

EXPERIMENTAL

THE ESTIMATION OF MANGANESE IN SOILS BY WALTERS' METHOD. —The soil, which had been ground to pass thru bolting cloth of 0.01 mm. mesh, was treated with hydrofluoric and sulphuric acids as described by Washington[5] and the manganese determined in the extract. The first part of Table 1 shows the results which were obtained on eight different soils. Soil No. 3,490 was selected to determine whether or not all of the manganese was rendered soluble with one extraction, and it was found that in some instances four extractions were necessary to completely remove all traces of manganese. In those samples where several extractions were made, the total amount of manganese obtained was nearly a constant, but even in these there is too great an error for exact work, for, altho the maximum difference between duplicates is only 0.010 per cent, this error represents almost 10 per cent of the total manganese present.

THE ESTIMATION OF MANGANESE IN SOILS BY OUR METHOD.— One gram of soil is intimately mixed with four grams of manganese-free dry sodium carbonate and fused in a 20 c.c. platinum crucible over a blast lamp until the melt is quiet, usually after about ten minutes fusion. The liquid mass is then poured into a platinum basin and the basin is rotated in order to obtain the melt in a thin film, thus providing for more rapid solution. The melt and the crucible are then treated with about

100 c.c. of distilled water and heated on a water bath in either a platinum or a procelain dish* until the fused product is completely disintegrated. The crucible is then removed from the dish, any adhering solution washed off, and the mixture acidified with 130 c.c. of 35 per cent (by weight) sulphuric acid and diluted to 250 c.c. This excess of sulphuric acid is employed inasmuch as the oxidation progresses more rapidly and basic bismuth salts do not precipitate. The same results may be obtained when half of this quantity of acid is used but the oxidation requires several minutes boiling and the permanganic acid solution must be filtered thru asbestos in order to free the solution from precipitated bismuth salts. Should there be a heavy precipitate of silica at this point it is advisable to filter, using a Büchner funnel and filtering by suction. This is seldom necessary, however, for in most cases the silica does not precipitate to any extent, but merely produces a slight opalescence which does not interfere with the permanganate readings. One hundred cubic centimeters of this solution is then placed in a beaker and from 0.25 gram to 1 gram of sodium bismuthate added, depending on the quantity of manganese present. We have found that 0.25 gram is sufficient where the manganese content does not exceed 0.20 per cent. The oxidation mixture is then heated to boiling and the boiling continued until the liquid has the true permanganate tint. If there is any red coloration the boiling has not been continued long enough. The solution is then cooled and read in a colorimeter or in Nessler's glasses against a standard solution of permanganic acid which has been prepared by reducing a solution of potassium permanganate in 20 per cent sulphuric acid by the cautious addition of sulphurous acid, and reoxidizing with bismuthate. This standard solution should contain about 0.2 mgr. of MnO per 10 c.c. From the ratios thus obtained the quantity of manganese in the original sample

is calculated. After a little practice, the complete operation can be carried out in an hour and a half, so that in this respect alone the method is greatly to be preferred.

When duplicate determinations are desired, only one fusion is necessary, for two separate oxidations may be taken from the total 250 c.c. In the data which are given in the last column of the table each figure represents a separate fusion and oxidation, and in the sixteen determinations, representing duplicate fusions on eight different soils, the maximum difference between duplicates amounts to only 0.002 per cent. No determinations were discarded in compiling this table.

manganous oxide found by Walters' method as described by Washington.

mber	MnO in 1st extraction	MnO in 2d extraction	MnO in 3d extraction	MnO in 4th extraction	Total MnO found	Per cent MnO found by our new method
0	0.082	0.020	0.004	Trace	0.106	0.109
0	0.080	0.027	0.005	?	0.112	0.111
0	0.060	0.012	Trace	?	0.102	.....
0	0.095	0.013	Trace	?	0.108	.....
0	0.095	0.013	Trace	?	0.108	.....
0	0.064	0.016	Not determined	.....	.....	.....
0	0.046	0.029	Not determined	.....	.....	.....
6	0.045	..........Not determined..........		.....	.....	0.107
6	0.052	..........Not determined..........		.....	.....	0.105
7	0.018	..........Not determined.........		.....	.....	0.111
7	0 028	...........Not determined		.....	.....	0.110
8	0.020	..........Not determined...... ...		.....	.....	0.111
8	.....	....		.....	.....	0.112
9	0.025	.... .Not determined.........		.....	.....	0.120
9	0.031	..........Not determined..........		.....	.....	0.119
1	0.044	... .Not determined		.....	.....	0.123
1	0.044	..........Not determined..........		.....	.....	0.125
3	0.060	...........Not determined		.. ..	.....	0.096
3	0.060	....Not determined..........		.....	.....	0.098
9	0 033	...........Not determined.....		.....	.....	0.067
9	.	....		.....	.....	0.067

SUMMARY

1. Walters' method for the determination of manganese is not applicable to soils, in some instances four extractions on a one-gram sample with hydrofluoric and sulphuric acids being necessary before all of the manganese is obtained in solution.

2. When such soils are fused with sodium carbonate and the solution of this melt is acidified with sulphuric acid and oxidized by means of sodium bismuthate, all of the manganese is oxidized to permanganic acid, and may be easily estimated colorimetrically.

3. We claim for this method greater rapidity, absence of irritating fumes, less danger of loss by spattering, more successful operation in inexperienced hands, duplicate determinations on a single sample of soil, and much greater accuracy.

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THE INHERITANCE OF THE LIGULE AND AURICLES OF CORN LEAVES

BY R. A. EMERSON

The membranous projection of the leaf sheath above the leaf blade in corn, known as the ligule, together with the somewhat leathery triangular connection between the sheath and blade, sometimes called the auricle, are so generally present in grasses that they are usually included in botanical characterizations of the grass family, tho they are not universal in this group. The only studies of the inheritance of the liguleless condition known to me are those reported with oats by Nilsson-Ehle[3] and by Wilson, the latter from a reference by Hurst.[2] So far as I am aware. the absence of the ligule and auricle has never before been reported for maize. The first corn plants lacking these leaf parts to come to my notice were found in one of my pedigree cultures grown at the Nebraska Experiment Station in 1910. No such plants have ever been found in any stock of my corn not related to that in which it was first seen. That the liguleless leaf character originated as a mutation in that stock of corn in that particular year is unquestionably not to be thought of. When where, or how it originated I have no way of knowing, and as to its possible present distribution outside of my own cultures I am equally uninformed.

The family of corn in which this type was first seen contained seventeen plants, every one of which showed the peculiarity. This family was the progeny of a self-pollinated plant grown the preceding year. The nature of this 1909 parent plant with respect to the peculiarity in question was not observed, but, from what is now known of the inheritance of the liguleless condition, it is reasonably certain that the 1909 parent plant must have exhibited the abnormality. That so striking a modification of the habit of growth of a plant as that caused by the absence of the leaf auricle (see fig. 1) should have passed unnoticed is explained by the fact that the plant showing it was enclosed in an individual cloth "tent" thruout the summer, a method of insuring self-pollination being tried experimentally at that time. Growing in the garden at the same time were six other plants from the same ear as that from which the parent plant of the 1910 liguleless family came. This was an open-pollinated ear of dent corn secured at the National Corn Exposition held in Omaha. These six sister plants (or half-sisters?) are all known to have had normal leaves. They were self-pollinated by hand in the usual way and three of them were represented by progenies among the 1910 families. On discovering the pure liguleless family in 1910, I examined these related families at once. Two of them were found to have both normal and liguleless plants, the combined numbers for the two families being 39 normal and 16 liguleless. The one other family had only normal leaved plants.

The facts noted above suggested at once that absence of ligule and auricle is a recessive trait and that the original ear from which all my liguleless families have come must have been borne on a normal leaved plant that was hybrid with respect to ligule and auricle. The facts already noted also indicated that the presence or absence of ligule and auricle in my strains of corn (unlike Nilsson-Ehle's oats) depends upon a single hereditary factor. These early indications have been borne out in later tests conducted both in the field during the summer of 1911 and in the greenhouse the past winter. Six liguleless plants have produced from self-pollination a total of 175 offspring, all liguleless. Four liguleless plants crossed with unrelated normal leaved plants have produced 103 individuals, all normal leaved. Twelve of these first generation hybrids yielded from self-pollination 572 normal leaved and 176 liguleless plants. One heterozygous normal leaved plant crossed with an unrelated homozygous normal plant produced four normal leaved offspring. On being self-pollinated, two of the four bred true, producing 96 individuals, all with normal leaves, and the other two yielded both normal leaved and liguleless progeny, 61 of the former and 29 of the latter. Lumping together all families in which both types of leaf have occurred, we find a total of 672 normal leaved and 221 liguleless leaved plants. To have given as nearly a 3 : 1 ratio as possible, the respective numbers need only to have been changed to 670 and 223.

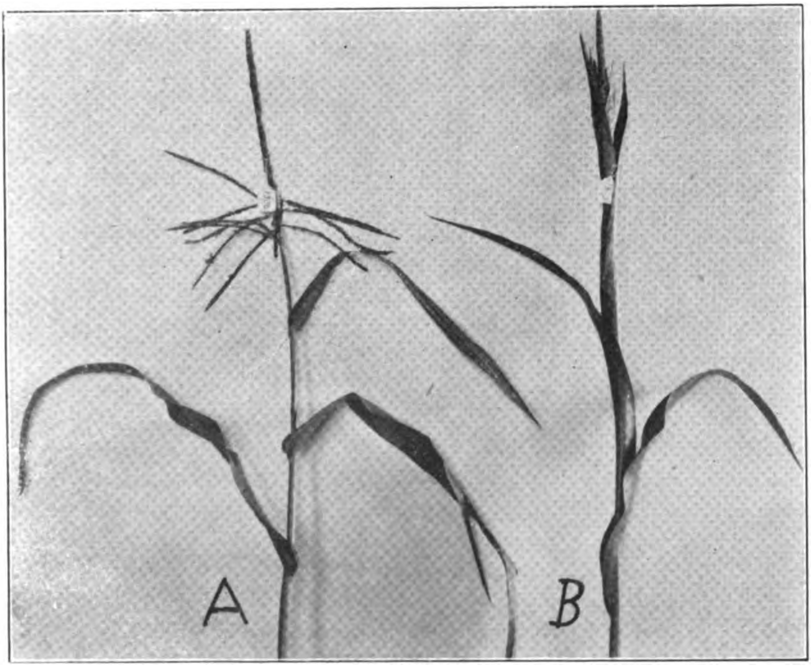

Fig. 1. *A*. Normal leaved corn plant. The auricles allow the leaves to stand out from the stalk. *B*. Liguleless leaved plant. The absence of auricles makes the leaves take an upright position.

The type of plant that I have here classed as liguleless lacks not only the ligule but also the auricle. In fact a few plants so classed have actually had a very poorly developed ligule, but the auricle, so far as I have been able to observe, has always been missing. Whether the absence of the ligule proper is disadvantageous to the plant is somewhat questionable. Some botanists, who look upon every persistent plant character as necessarily serving some good purpose, have suggested that the ligule serves to keep the water collected by the leaf blade from running down the stalk underneath the sheath where it might help to bring about decay. My own observations on liguleless corn are to the effect that the inside of the sheath is more often discolored, as if from incipient decay, than is the case when a well-developed ligule is present. In no case, however, have I found decay of the stalk or leaf sufficient to be of any material injury to the

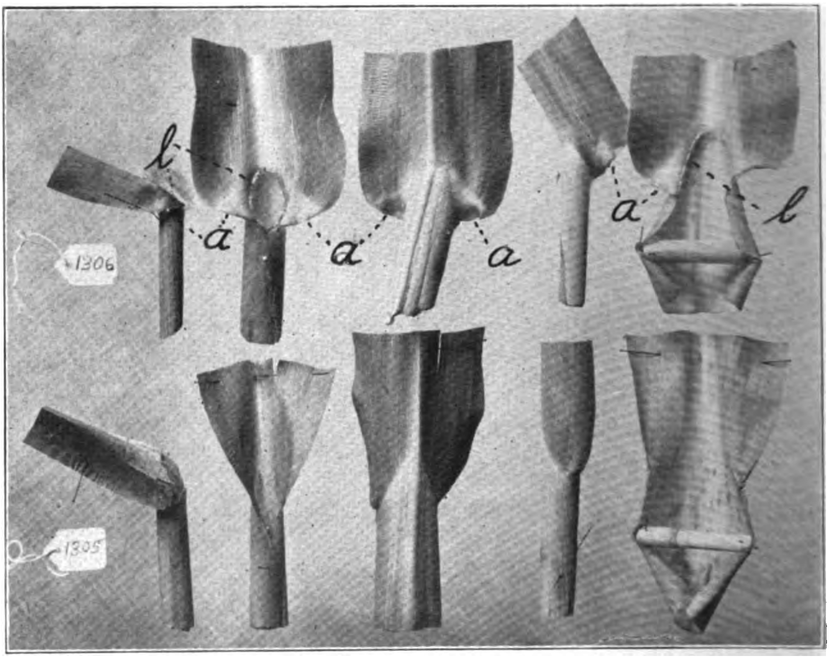

Fig. 2. Details of normal leaves (upper row) and of liguleless leaves (lower row). The auricles permit the blades to flatten out abruptly at the top of the sheath and also to bend away from the stalk at a sharp angle. The non-auriculate leaf is torn when the blade is bent abruptly backward (see extreme left of figure). *a*=auricle. *l*=ligule.

plant—not even during the past summer when the plants were grown near Boston where they were exposed to moister conditions than is usually the case in Nebraska.

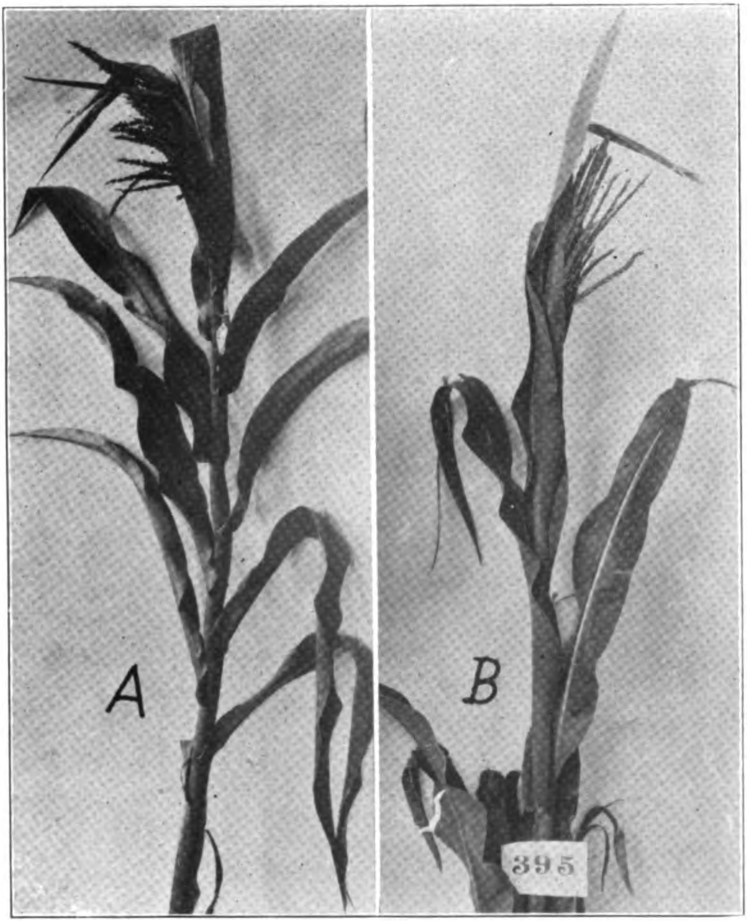

Fig. 3. One-sided arrangement of upper leaves, forming a hood for the tassel. *A* is a normal leaved pop-corn and *B* a liguleless leaved dent corn.

Whatever the effect of the liguleless condition upon the well-being of the plant, it apparently has nothing to do with the peculiar habit of growth so characteristic of the liguleless type. (See fig. 1.) It is rather the absence of the auricle that makes the leaves stand so erect. In ordinary corn the leaf blade forms a more or less sharp angle with the sheath, the angle in any particular case depending much upon the size and stiffness of the midrib. It is the triangular shape of the auricle that makes possible the immediate flattening out of the leaf blade at the termination of the cylindrical sheath and that allows the blade to bend abruptly away from the stalk while the sheath still clasps it. In leaves that lack the auricle, the blade can neither be flattened out directly at the end of the sheath nor bent back sharply without either flattening out the sheath also or else tearing the blade away from the rolled up sheath. (See fig. 2.) It results therefore, in case of non-auriculate leaves, that not only the sheath but the lower part of the blade as well is rolled somewhat closely about the stalk and that the leaf as a whole assumes an upright position nearly parallel with the stalk, the tip of the leaf curving away gently if the blade is long and the midrib sufficiently flexible.

What effect this peculiar leaf habit may have upon the growth and productiveness of corn is not known. It seems reasonable that the lessened exposure of the leaves due to rolling about the stalk should reduce transpiration, and if so might possibly also retard photosynthesis. Further, the growth of the leaves up about the tassel might serve to protect the pollen from injury in extremely dry seasons but certainly causes it to rot in seasons of abundant rainfall, except when the upper leaves are arranged on one side of the tassel as described by Collins[1] in a certain Chinese corn. (See fig. 3.) In short, if this type of plant has any place in practical corn production it will doubtless be found

It has been combined with stocks that throw white seedlings and with others that contain the dwarf-hermaphrodite abnormality. (See fig. 4.) So far, no definite correlation has been observed between liguleleseness and any other character except that of the non-auriculate condition, and these two conditions may, of course, be due to a single hereditary factor. The sharpness with which the non-auriculate condition segregates out in second generation hybrids and its inheritance independent of several common char-

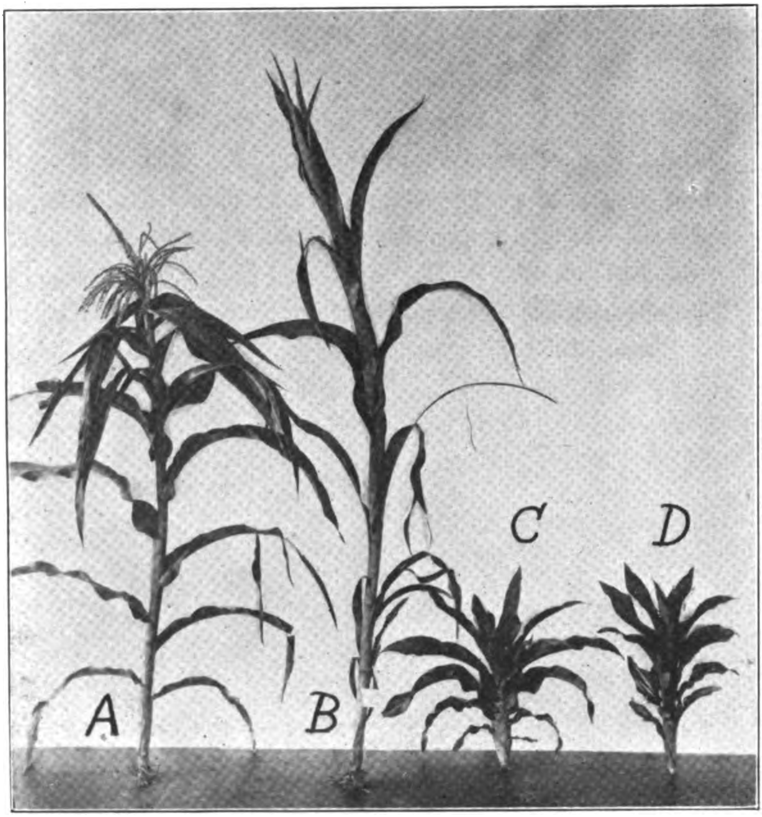

Fig. 4. *A*, tall, normal leaved; *B*, tall, liguleless leaved; *C*, dwarf, normal leaved; *D*, dwarf, liguleless leaved plants from an F_2 family. The ratio approximated is 9 : 3 : 3 : 1.

acters in corn would make it possible to combine it with various commercial types of corn if it should prove a desirable character for particular localities and also would make it easy to rid a strain of it should it prove disadvantageous in certain environments.

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THE INHERITANCE OF CERTAIN FORMS OF CHLOROPHYLL REDUCTION IN CORN LEAVES

BY R. A. EMERSON

The presence of chlorophyll in the leaves of corn, and indeed of all grasses as well as of most other flowering plants, is so nearly universal that few perhaps have thought of it as a character that is inherited in accordance with a definite law any more than that the roots of these same plants are inherited "characters." While no one doubtless would deny the inheritance of chlorophyll, it is obviously impossible, just as with other characters, to determine experimentally the manner of its inheritance until plants lacking it are found. Such plants occur occasionally in corn, as they do also in many other kinds of the higher plants. Most such white plants of course perish as soon as the food stored in the seed is exhausted since they have no means of making food for themselves. Only such plants as have the ability to live as parasites or saprophytes can persist after having lost the power to produce chlorophyll.

From the fact that white corn plants always die within a few weeks of the time they appear and can not therefore reproduce themselves directly, it must not be inferred that their reappearance year after year is due to production anew by mutation each succeeding generation. Knowing, as we do now, that the absence of chlorophyll in corn is a simple Mendelian recessive, we see readily that a single mutation resulting in the loss of the ability to produce chlorophyll might account for all the white seedlings that have since occurred. If in the production of a single gamete there were lost the ability to start or to complete properly a series of reactions ending in the normal production of chlorophyll, this single gamete, in order to produce a plant, must unite with a gamete that is normal in respect to chlorophyll production. Such a union would result ordinarily in a fully green plant not distinguishable from a homozygous green individual. If self-pollinated. 25 per cent of its progeny should be pure white and would of course perish; 25 per cent should be pure green, yielding only green offspring; and 50 per cent should be green but hybrid like their parent, yielding in turn, if selfed, progenies containing 25 per cent of white seedlings. But if the original hybrid-green mutant should be largely cross-pollinated by pure normal green plants, as would be most likely, white seedlings might not appear until the third or some later generation and would never occur of course except by the union of two germ cells both lacking the ability to bring about chlorophyll formation. And in the meantime the several hybrid green plants, tho normal themselves, would have been producing germ cells one-half of which lacked some factor necessary for chlorophyll formation and would thus have been scattering the abnormality broadcast. Tho I have observed the occurrence of white seedlings in many of my corn families, I can not say that any of these plants have been due to a mutation occurring in my pedigree cultures. All of them are readily traced back to a very few plants used in my original crosses as will be indicated more clearly in the account of the breeding experiments given below.

In 1909 a single corn plant was found to be prominently marked with longitudinal stripes of green and white varying greatly in breadth, very much like some of the variegated varieties of maize and other grasses sometimes grown as ornamental plants. This plant was self-pollinated and also crossed with a fully green plant. No record was made of the progenies of this plant in 1910 until the seedlings were a foot or more high, at which time it was found that there was a poor stand in case of the plants grown from selfed seed and a fairly good stand of plants grown from the crossed seed. Not a variegated plant was found in either lot—all were fully green. The following winter.

seeds from both of the two 1910 lots were germinated in the greenhouse. Again no striped plants were seen, but several pure white ones appeared along with the green ones. (See fig. 1.) These white plants of course all died in a few weeks owing to their inability to manufacture carbohydrate food. This sug-

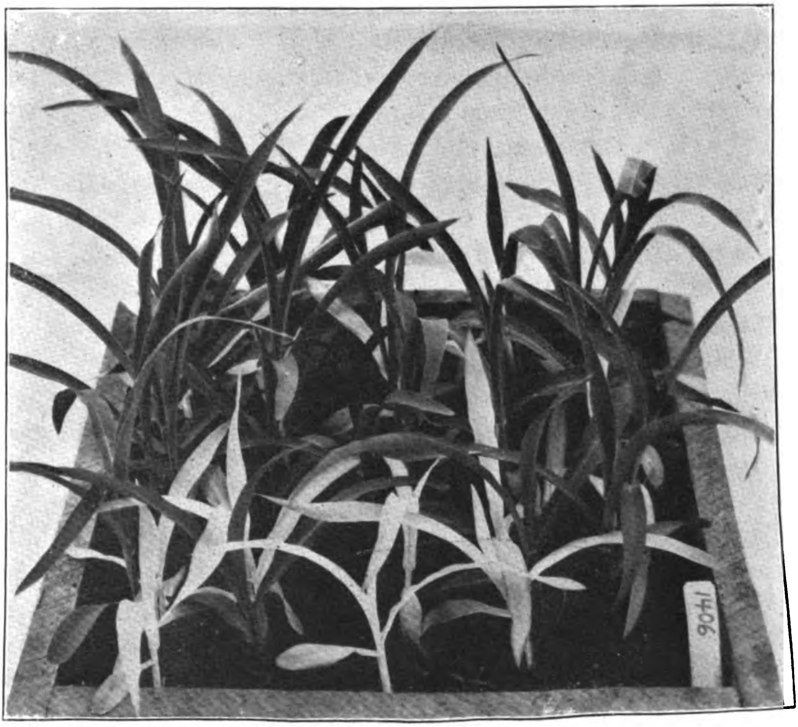

Fig. 1. Green and white corn seedlings in a greenhouse seed flat. The white seedlings had ceased growing before the photograph was taken and died within a few days afterward.

many white plants and their subsequent destruction. The matter was tested at once by planting the remaining seeds from the selfed ear of the original variegated plant. Five green and three white seedlings resulted. Various tests were also made with seed from plants of the 1910 lot resulting from the cross of the variegated plant with a fully green plant. These tests resulted as expected in the appearance of both green and white seedlings in the progenies of some plants and only green seedlings in other cases. Numerous tests have since been made with this stock of corn and a large number of seedlings grown, all of which have been either fully green or fully white except eight individuals which have been prominently variegated like the original plant from which these families arose. Apparently in this stock of corn green is usually fully dominant, but occasionally is imperfectly so, resulting then in a variegated plant.

White seedlings have also occurred in stocks of corn unrelated to the families noted above. One of these cases is of particular interest. One of the original plants of this stock, itself fully green, was crossed with various pure green races, and of course produced nothing but fully green first-generation offspring. It was not, therefore, until white seedlings were found in several second-generation progenies, all tracing back to this same grandparent, that its real nature was indicated.

In all, white seedlings have now been recorded in forty-one distinct progenies, but the pedigrees of all these trace back to only five apparently unrelated stocks of corn. When all the forty have produced white plants, the "white" seedlings have been yellowish-white at first, the older leaves soon becoming yellowish-green and later a fairly strong green. None of the greenish-white seedlings under observation has ever lived to mature tho it is not uncommon for them to live a week or two longer than the pure white seedlings, and one such plant lived to the age of seven weeks. While the two kinds of "whites" are doubtless distinct, their interrelations have not been carefully studied as yet.*

While the nature of this abnormality renders it impossible to produce a strain that breeds true white and that can be crossed directly with true green strains, it is none the less evident, as suggested by East and Hays,[7] that the white seedlings are homozygous recessives. The green plants in any family in which white seedlings occur must then be of two sorts, one homozygous green, producing nothing but green offspring, the other heterozygous green (sometimes variegated), yielding on self-pollination about three green seedlings to one white one. There should of course be one pure green to two hybrid green plants. Of 43 plants tested from such families, 15 have been found to breed true to the green color and 28 have produced both green and white seedlings. Similarly, of plants from all-green families resulting from a cross of pure green plants with hybrid green ones, half should breed true green and half produce both green and white seedlings. Of 17 plants tested from such families, 9 have produced green plants only and 8 have yielded both greens and whites.

Mention has been made above of the occurrence of prominently variegated plants in some families that produce about 25 per cent of white seedlings. Such plants are usually noticeably striped from the beginning and may show less or more white as they grow larger. In the latter case they may eventually die thru their inability to produce a sufficient amount of food. Only two of these variegated plants have been tested and they both proved to be heterozygous for green color, having produced full greens and pure whites in the next generation. Whether any such prominently variegated plants are ever homozygous for green color can not be said. They occur only very rarely, only 9 having been seen in progenies totaling over 1,900 individuals, over 1,450 of which were green and in which therefore nearly 1,000 should have been heterozygous for green. It is perhaps worthy of note that eight of the nine variegated plants appeared in one stock and only one such plant in an unrelated stock. It might be thought from this that the variegation here seen is a pattern character independent of the presence of green color. Considering only those families in which variegated plants occurred, there were 175 fully green plants and 9 variegated ones, or a ratio of 19.4 : 1. The ratio in the several families varied from 9 : 1 to 26 : 1. This suggests the possibility of there being two factors such that only in the absence of both is the plant variegated. Such a condition would be expected to give ratios approximating 16 : 1, as found true for certain colors in wheat and oats by Nilsson-Ehle[8] and for yellow endosperm in corn by East.[6] If this were true with respect to variegation in these corn families, some families showing 3 : 1 ratios are to be expected, and indeed one such family is known, and is discussed later in this paper. The one fact, however, that positively disproves this hypothesis for these cases of variegation is that the two variegated plants tested were not homozygous for variegation, but on the contrary one of them produced only two variegated plants in a progeny of twenty while the other produced no variegated offspring in a above. The family consisted of 118 individuals, 30 of which were apparently pure white and of course died as seedlings. The other 88 plants were examined carefully for variegated individuals while still small and again somewhat later without the discovery of a single variegated plant. At blossoming time, however, it

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* A preliminary examination of these pure white and yellowish white seedlings indicates that from the former plastids may be entirely absent while in the latter they are apparently present from the first, tho fewer in number and much smaller than the plastids of normal green seedlings or of seedlings made yellowish by being grown in darkness. These studies are being conuucted at my suggestion by Mr. F. C. Miles, a graduate student in genetics. The study includes an examination of both fresh material and of paraffin sections stained with Lichtgrün, iodin green, Delafield's haematoxylin, or acid fuchsin.

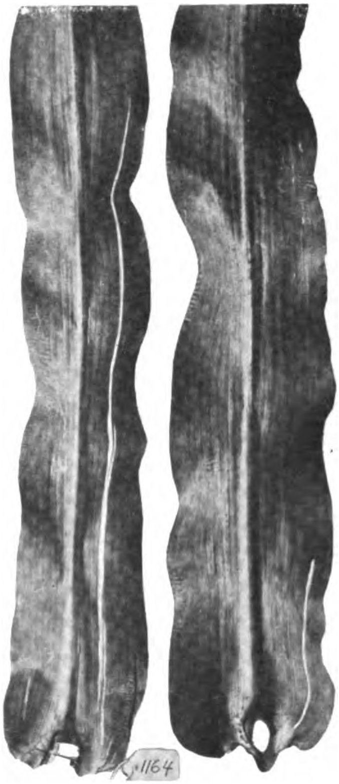

Fig. 2. Inconspicuously variegated leaves—a single narrow white stripe on each leaf.

accurate classification of such material is almost impossible, since a plant, thru some injury to the only variegated leaf it has, might be classed as fully green. Of the 88 plants that survived in this family, 22 were classed as inconspicuously variegated, while on the other 66 plants no striped leaves could be found. The observed numbers, 66 fully green, 22 slightly striped, and 30 white, give almost exactly the common dihybrid ratio of 9 : 3 : 4, suggesting that in this family presence of green color and inconspicuous variegation may be distinct characters independently inherited. If this is true, variegation here must be recessive to self color (green) and should therefore breed true. Another generation must be grown before the matter can be cleared up. The question cannot be determined from greenhouse cultures because the seedlings show no stripes.

A bit of evidence indicating that this inconspicuous variegation may not be due to heterozygosis of green, as seems to be true of the prominent variegation occurring rarely in another stock noted above, is afforded by several cultures of seedlings germinated in the greenhouse during the past winter. From the inconspicuously variegated plants of the family under consideration, ten progenies were started, eight of which contained white seedlings and *two of which had only green seedlings*. Similarly, from supposedly fully green plants of the same family four progenies were grown, three of which yielded only green seedlings and one both green and white seedlings. If no mistakes were made in classing as variegated two of the plants that yielded wholly green progenies—and such a mistake while not impossible is less likely than the opposite mistake of classing a slightly variegated plant as fully green—certainly this inconspicuous variegation is not an indication of heterozygosis of green color.

It is well known that there are varieties of corn that have prominently variegated leaves and that breed true to that condition. Such varieties are not uncommonly grown as ornamentals by gardeners. Only two such sorts have been included

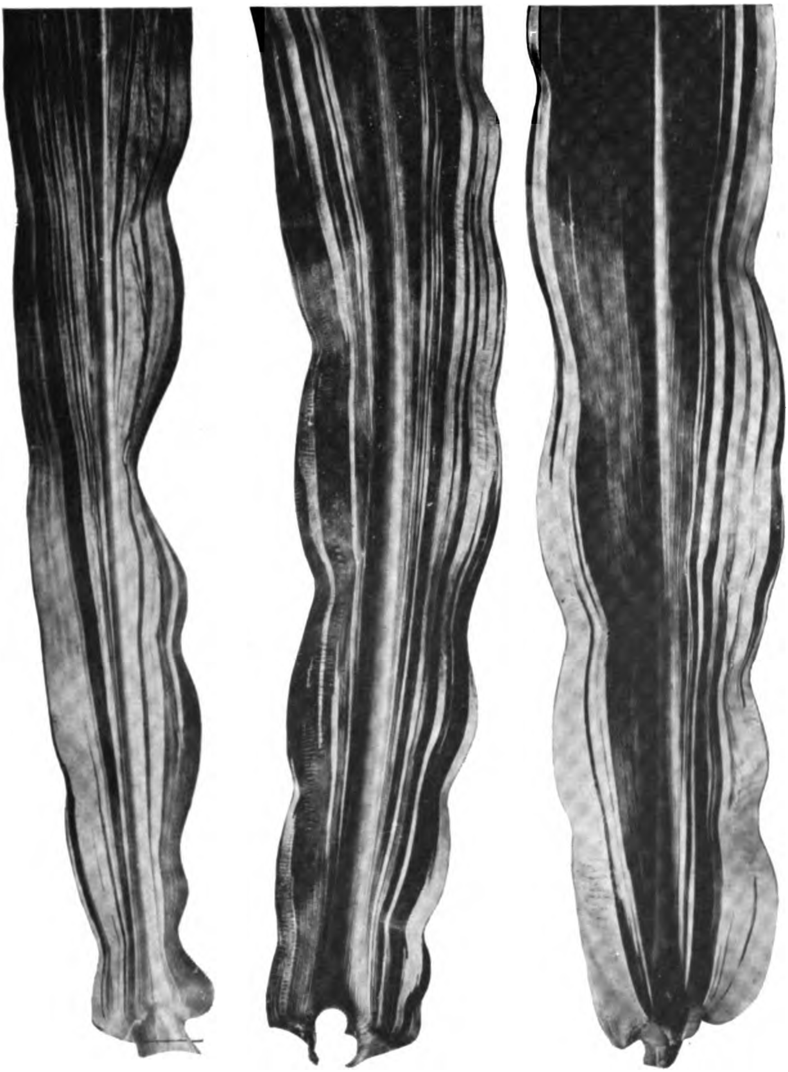

Fig. 3. **Prominently variegated leaves of *Zea Japonica*—variable stripes of green, pale green, and white.**

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in my cultures. The seedlings are usually unmistakably, tho never prominently, variegated. The older plants have prominent longitudinal stripes of green, white, or yellowish, and pale green of variable width and length.* (See fig. 3.) A single cross between one of these striped varieties, known as *Zea Japonica*, and a fully green sort produced 34 seedlings all fully green in the seedling stage. Three of these were grown to maturity in the greenhouse without the appearance of a single stripe. No second generation has been grown but the indications are that this type of variegation is a recessive character.

A single family of corn, distantly related to the stock in which the first variegated plant seen in my cultures occurred, was found to contain 57 apparently fully green plants, 14 variegated ones, and 2 that were recorded as white. The latter may, however, have shown merely an extreme form of variegation, since the variegated plants varied from green with narrow white stripes to white with a few narrow green stripes. The parent of this family was a fully green plant. This would suggest that, in this case, variegation is a recessive character and that the segregation is possibly of the simple three-to-one sort. Another family closely related to this one contained 55 fully green plants and 3 prominently variegated ones. This suggests that perhaps here two independent factors are concerned, either one of which may bring about the fully green condition, so that variegation can occur only in the absence of both. More evidence, however, is needed before any conclusion can be reached regarding the inheritance of this character.

The fact that the variegated plants of these two families are prominently striped even in the seedling stage, while the seedlings of the variegated varieties grown by me are not noticeably striped tho the mature plants of all are very similar, suggests that distinct types of variegation may be concerned. It is of course equally possible that all the types of variegation noted in this paper may be due to the same thing and that the characteristic differences in appearance are due to the presence of and interaction with other diverse characters in the several stocks.

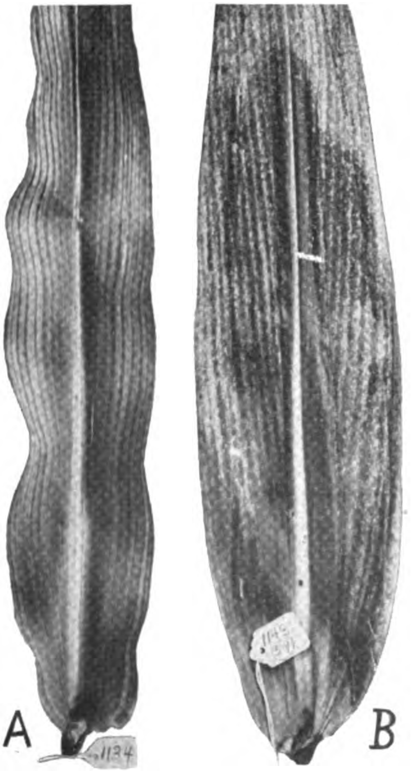

Fig. 4. *A*. Corn leaf showing regular stripes of dark green about the veins, and of pale green between them. *B*. Spots of yellowish-green coalescing in rows to form broken yellowish stripes between the veins.

A distinct type of striping, not variegation, was seen in one family of corn in 1911. The stripes run lengthwise of the leaves, but, instead of varying greatly in breadth and even in length as is true of variegated leaves, are all uniformly narrow and extend thruout the entire length of the leaves. (See fig. 4, *A*.) The regions traversed by fibro-vascular bundles are uniformly dark green like normal leaves while the regions between the bundles are uniformly very pale green. There were in this family 112 plants with normal green leaves and only 19 plants with striped leaves at the time the plants were full grown. A number of plants died while small. The striped leaved plants were somewhat smaller and also noticeably later in blossoming than the normal plants. The height of the striped plants averaged 109 centimeters while that of the normal plants was 129 centimeters. The average number of days from planting to blossoming time were 81.4 for the striped plants and 68.3 for the normal plants. No examination was made of the chlorophyll of the light colored stripes, but there was apparently a deficiency of it and the striped plants seemed to be in a more or less pathological condition thruout their period of growth.

The numbers given above afford the only indication I have of the manner of inheritance of this abnormality except that no striping was noted in the parent of this family and that it was probably of normal green color. Taken together these facts suggest that this striping is a simple Mendelian recessive. That the character is really inherited rather than due to a "diseased" condition of a few of the plants of the 1911 family is made probable from the fact that two cultures grown in different parts of the field from the same parent plant both contained the striped plants in about the same percentage while no similarly striped plants occurred in any other family in either part of the field.

In 1910 twenty-four plants of a light yellowish-green color were found in a small plat of silage corn. They resembled in color the so-called "golden" varieties of various ornamental shrubs. That they possessed considerable chlorophyll was indicated by their color and by the fact that all twenty-four plants grew to nearly normal height and produced pollen in abundance. That they were deficient in chlorophyll was indicated not only by their color but also from the fact that not one of the twenty-four plants was able to produce a single ear of corn. Obviously no progenies could be grown from these plants. A fair ear was found, however, on a similar yellow plant in another field and the progeny of this open fertilized plant contained a considerable percentage of yellow plants in 1911, thus indicating the hereditary nature of the yellow character. Two plants of pure green families were crossed with pollen from one of the barren yellow plants of 1910, and the plants of the 1911 progenies, a total of 137, were all fully green, thus indicating that this type of chlorophyll reduction, like those already considered, is a recessive character. No examination of the chloroplasts of this yellow corn has been made.

Mention should also be made of a peculiarly spotted and striped appearance of the leaves of certain maize families noticed first in 1911. At about the time of blossoming, or somewhat earlier, the leaves began to show numerous small, roundish, yellow-green spots. In some cases the spots remained distinct thruout the remainder of the life of the plant, but in many cases they coalesced in rows to form broken stripes between the veins. (See fig. 4, *B.*) Not infrequently the yellowish green tissue died before the plants matured. Nothing is known of the inheritance of this peculiarity and it would therefore not have been mentioned here had it not been for these facts: First, that it was limited definitely to certain families as grown in the summer of 1911, and second, that the plants grown in the greenhouse during the following winter from seed of spotted plants all developed the same spotted appearance, thus indicating that this condition may be inherited. No parasitic organism has been found in connection with the yellow spots by the Department of Agricultural Botany, to which the matter was referred. No attempt has been made to determine whether the spotted condition can be transferred to healthy plants by inoculation as in the case of "enzymatic" diseases.

In conclusion it may be said that reduction of chlorophyll in corn is of several kinds. *First,* the entire absence of chlorophyll and apparently even of plastids, resulting in the early death of the seedlings. It behaves in inheritance as a simple Mendelian recessive. Here the heterozygous plants are usually fully green but in rare cases may be prominently variegated white and green. *Second,* the almost complete absence of chlorophyll and a marked reduction in plastids resulting in yellowish-white seedlings that may later become more or less greenish, but which so far as observed never live more than a month or two. This is also a simple Mendelian recessive. *Third,* apparently a partial reduction of chlorophyll in the growing and mature plant, resulting in a yellowish-green color not noticeable in the seedling stage. Such plants rarely mature good ears but produce pollen in abundance. The character is certainly not a dominant one. Its inheritance has not been fully investigated. *Fourth,* the entire or partial absence of chlorophyll from a few very narrow streaks in some leaves. This results in a type of very inconspicuous variegation. Tho occurring in a family that produced pure whites, it is probably not due to heterozygosis of green. It is apparently a recessive character. *Fifth,* the partial or complete absence of chlorophyll from more or less broad and elongated areas of the leaf resulting in prominent longitudinal stripes (variegation) of green, pale green, and white. Apparently this is a Mendelian recessive. In some cases it may be able to appear only in the absence of both of two positive factors. Perhaps more than one type of variegation is included here. *Sixth,* a definite narrow striping of the leaf, not a form of variegation. In the region of the fibrovascular bundles, the leaf is dark green, while between the bundles are narrow stripes of very pale green. These striped plants are uniformly smaller and later than fully green plants of the same family. The condition is apparently a Mendelian recessive. *Seventh,* the appearance of yellowish spots coalescing into rows between the veins of the leaf and sometimes causing (?)

the death of the yellowish tissue. This is apparently not due to a parasitic organism. It has appeared in two successive generations of the same stock of corn, suggesting that it may be an inherited character.

Almost nothing is known as yet of the possible interrelations of these different forms of chlorophyll reduction. In so far as their inheritance has been carefully studied, they have been shown to be Mendelian recessives.

The behavior of the prominently variegated plants, which occur rarely in families made up of about three fully green plants to one white plant and which are, at least in some cases, heterozygous for green color, is of particular interest. In some respects their behavior resembles that observed by Baur[2] in case of a variegated (mosaic) *Pelargonium,* but in essential features it is fundamentally different. Mosaic pelargoniums Baur found to vary, just as these variegated corn plants do, from nearly white to nearly green, some branches being wholly green, some wholly white, and some in part white and in part green (sectoral chimeras). Reciprocal crosses between white and green branches of a mosaic plant, or between white branches and any green race, were all mosaics of white and green. Selfed flowers on mosaic parts of these plants produced wholly green and wholly white seedlings like the variegated corn plants here under consideration, but the ratios in case of *Pelargonium* were extremely variable, whereas with maize they always approximate 3 : 1. Moreover the green pelargonium plants thus produced are always homozygous, while in case of corn about two-thirds of them are heterozygous. With *Pelargonium* selfed seeds from green branches of mosaic plants always breed true green and seeds from white branches bred true white, a matter that I have not been able to test in case of corn. In short, while the mosaic of green and white in *Pelargonium* and in this particular lot of corn is apparently due to heterozygosis, the behavior in later generations shows the case of corn to be merely simple Mendelian inheritance, while the *Pelargonium* is one of only two certainly known cases of non-Mendelian inheritance that have been reported.

It is interesting to add further that Baur has reported another case of leaf color in *Pelargonium* that mendelizes typically. The case concerns crosses of yellow leaved forms (not capable of independent existence) with green leaved sorts, in which F_1 is "golden" leaved and F_2 is made up of the three types in the monohybrid ratio 1:2:1. Other cases of Mendelian inheritance of green color have also been reported for *Antirrhinum* by Baur.[1] There is as yet no indication that in *Zea* there is to be found any sort of non-mendelian inheritance of green color, either like that noted above for *Pelargonium* (Baur[2]) or like that observed by Correns[3, 4] in *Mirabilis Jalapa,* where both the green and the white conditions are inherited thru the mother only.

No opportunity has as yet occurred to determine the behavior of fully green shoots of true-breeding, variegated maize plants. Whether they will be found to be heterozygous for green as Correns[5] found to be true in case of *Mirabilis* can not therefore be told.

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THE MOISTURE CONTENT OF FIELD SOILS UNDER DIFFERENT TREATMENTS

BY P. B. BARKER

The soil moisture data here presented are a compilation of figures procured from the fields of the University Farm during the past three years. Soil moisture investigations have been in progress at the Experiment Station for five years and an immense amount of data has been collected from which much information may be ascertained concerning the water in the soil.

The soils experimented with are mostly silt loams and known as Marshall silt loams. According to the Lancaster Soil Survey Sheet, over 60 per cent of Lancaster county is composed of this type of soil. This type contains more than 55 per cent silt and from 10 per cent to 25 per cent clay.

It was thought advisable to present the moisture content of only the fields of corn, small grains, and alfalfa, and one field which was summer tilled. The data here presented are, for sake of brevity, further limited to the months of June, July, and August.

The moisture content of the fields is ascertained for each of the uppermost six feet at least twice per month—once at the beginning and once near the middle of each month. It is thought best to present, in this paper, only the data from the six-foot sampling made about the first of the month. Besides the six-foot samplings, several two-foot samplings were made at intervals of two or three days, which permit of more detailed study of the soil moisture.

The samples are taken by means of a set of soil tubes. This enables the operator to obtain representative samples from each foot.

It is the practice at the Station to obtain composite samples from each foot in depth by taking samples from several places in each field and mixing the corresponding samples from each foot section. For instance, a composite set of samples from field A may represent samples taken at several different places in order to obtain samples that are representative of the field. The samples taken at the several places for the first foot are thoroly mixed and a small sample obtained. In the same way composite samples are obtained from each foot in depth of the field.

The samples are dried at 110° C. and the percentages computed, using water-free soil as the basis of calculation. Notes are taken on the appearance and condition of the crops at each sampling, thus correlating the condition of the crop with the moisture content of the soil.

The following tables represent the moisture content in the corn, small grain, alfalfa, and summer tilled fields for each of the uppermost six feet.

Each of the columns headed June, July, and August is an average of the moisture contents at the beginning of each respective month in 1909, 1910, and 1911. For instance, the column headed June represents the average of the moisture content at the beginning of June for the three years mentioned above.

MOISTURE CONTENT OF FIELD SOILS

	SMALL GRAINS			ALFALFA		
Depth	June	July	August	June	July	August
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	19.19	17.61	15.18	20.90	21.95	19.48
2	19.70	18.96	18.42	25.42	21.81	21.25
3	21.07	19.51	18.13	24.97	19.94	20.71
4	19.69	19.00	17.86	20.86	17.42	18.08
5	24.69	22.60	21.01	20.65	17.91	17.22
6	25.90	23.02	24.97	20.39	18.19	17.39

	CORN				SUMMER TILLAGE		
Depth	May	June	July	August	June	July	August
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	22.70	28.49	23.72	18.83	26.65	24.75	25.95
2	28.80	28.28	27.36	21.32	27.95	25.90	25.90
3	....	23.56	25.66	20.91	23.85	23.60	24.50
4	.....	22.26	22.76	21.31	23.70	25.00	23.70
5	.....	23.48	23.72	24.26	26.90	25.85	25.40
6	.....	26.19	24.97	25.74	25.85	26.10	26.25

It is interesting to correlate the size and conditions of the various crops with the moisture content of the respective fields at the time of sampling and, consequently, the following notes should accompany the tables:

CORN.

June 10. The corn was usually about six inches high at this time and had been cultivated once.

July 1 to 12. The corn is usually growing very rapidly at this time of the year and a few days may cause a great difference in the height, but it ranges from about 2 to 5 feet during the first half of July. The roots are thoroly established and consequently the crop may be transpiring one or two inches of water per week.

August 3 to 12. The height of the corn varied during the early part of August from about 10 feet in 1910 to 6 feet in 1911.

SMALL GRAINS

June 10. The wheat was about 2½ to 3 feet high June 10 for each of the past three years and consequently was using a large amount of water. The oats were about sixteen inches high at this time of the year. The small grain crops were growing nicely at this time for the first two years, while the surface soils were rather dry at this time of the year in 1911 and the lower leaves were falling off.

July 1 to 15. The wheat and oats were harvested from the 1st to the 15th of July. The upper three feet were usually rather dry.

August 1. The wheat and oat land on which these soil moisture experiments were conducted was disked and plowed about August 1. The stubble fields are usually treated differently in order to ascertain the effects of the different treatments on the moisture content.

ALFALFA

June 10. The first cutting of alfalfa is usually done near this time, when it is generally about 18 inches high.

July 1 to 12. This is approximately the time of the second cutting of alfalfa. The alfalfa usually makes a large growth during the months of June and July.

August 3 to 15. The third cutting of alfalfa is generally made about this time of the year.

A FEW NOTES CONCERNING THE ACCOMPANYING TABLES

1. The summer-tilled fields contain more water at all depths during June, July, and August for the years 1909, 1910, and 1911 than those producing wheat, oats, or alfalfa.

2. The moisture content is also comparatively uniform in the upper six feet and thruout the growing season.

3. The moisture data shown in the columns under June and July in the corn table are similar to the amounts in the summer-tilled fields, largely because the corn does not begin to use excessive quantities of water until July. It may be well to remind the reader again that the moisture contents here shown were ascertained at the beginning of the various months and consequently the percentages of moisture in the July column represent the conditions for the latter part of June and the early part of July.

4. The small grain crops contain the least percentages of moisture in the upper four feet in June, July, and August for the years under consideration.

5. The alfalfa and brome grass fields contain a lower per cent of moisture in the fifth and sixth feet than any of the other fields represented in the tables. They contain a trifle more water in the upper three feet than the small grain fields.

6. The moisture content of the small grain fields increases with the depth in the upper six feet, while the moisture content of the alfalfa fields decreases with depth from the second foot.

7. The moisture content of the cornfield decreases from the second foot to the fifth, when it begins to increase.

8. It is evident from a comparison of the tables that transpiration is a very important factor in causing a reduction in moisture content of soils.

9. The loss of water due to direct evaporation from the surface of the soil is a very small factor after the water becomes thoroly distributed in the soil.

According to the Rothamsted Experiment Station, about 50 per cent of the rainfall is evaporated under England's conditions and no doubt a large proportion of it is lost thru evaporation under Nebraska conditions when no vegetation is growing on the land. But the loss takes place mostly when the surface soil is very wet, before the moisture is thoroly distributed thruout the soil, and before the soil is in a good tillable condition.

TESTS OF CORN PLANTERS WITH GRADED CORN

By L. W. Chase and C. F. Chase*

Of late years there has been much said and published about the accuracy of drop of corn planters, the conditions influencing it, and its effect upon the resulting crop. The questions that have arisen are, shall we use the edge-selection or round-hole planter plates, and shall we grade our seed corn with a corn grader, by hand, or not at all? The work recorded was undertaken in an attempt to answer these questions.

Early experimenters found the kernels from both the butt and the tip ends of the seed corn ear to produce as well as those taken from the middle, provided their germinating power was not injured. Also, it is evident that the grader can not select the strong kernels from the weak further than by removing a few defective ones, which can be as easily removed with the fanning mill. The tests herein tabulated are purely mechanical and show how the removal of the irregular shaped kernels will influence the accuracy of drop of the planter. (By accuracy of drop is meant the placing of the exact number of kernels in each hill which the operator of the planter desires.)

Before starting the work a circular letter was mailed to the corn experts of some of the principal corn producing states. Eight questions bearing more or less upon the use of the corn planter and its effect upon the resulting yield of corn were asked. Questions and replies were as follows:

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Questions	Replies			
	1	2	3	4
1. If all the planters in your state planted accurately, how much would it increase the yield?	No evidence.	Don't know and do not like to guess.	Ten bushels.	10 per cent.
2. If a planter drops the correct number of kernels per acre, but drops from one to five kernels per hill with, say, 50 per cent containing three kernels, how much will it affect the yield, if any?	Two years' work indicate the yield would not be materially affected, provided the number of plants per acre remain the same.	Don't know how much, but it will make a difference.	Perhaps three or four bushels.	(Indefinite answer.)
3. How many kernels should be planted on an average acre, providing 95 per cent of them produce a stalk?	10,000 to 16,000 on fertile soil. 7,000 to 12,000 on medium soil.	Depends on quality of soil, variety of corn, etc.	10,800.	Rows 42 inches and kernels 15 to 18 inches apart, one to a hill.
4 What per cent of the kernels planted produce stalks under average conditions?	80 to 85 per cent.	Depends largely on viability and the crows.	60 per cent.	75 to 85 per cent.
5. How deep should corn be planted?	Depends—deep enough to insure moisture and good germination.	Depends on several conditions.	One and a half to two inches.	Varies. Average two inches.

Questions	Replies			
	1	2	3	4
6. How far apart should the rows be to produce the best results?	....	Same as 5.	Three feet and six inches.	Three feet and six inches.
7. Which is the more satisfactory, corn planted in hills or in drills, the hills being the same distance apart as the rows and both top planted?	Hills, because of cultivation.	Usually hill planting is preferable, because it can be cultivated both ways, making it easier to cope with weeds.	Planted in hills.	The method of planting the corn in drills has given the best results at this Station.
8. What is your opinion of the furrow opener?	Good for light soils. Its heavy draft is objectionable.	Usually a good thing if coupled with discretion.	It gets the kernel down into the surface soil which has been turned under (a more favorable seed-bed) and probably aids cultivation.	We have carried on extensive experiments with the disk furrow opener and in every case this has given increased results.
Remarks	None.	Most of the above are useless questions, as each of half a dozen answers might be correct—depending upon conditions which are found to vary and are not the same two years at a time even in the same field.	These answers are of course more or less general, as we have never given any of it very close consideration.	None.

The above information is of especial interest to the careful observer and emphasizes the fact that each individual farmer must be the judge of his own conditions to a large extent.

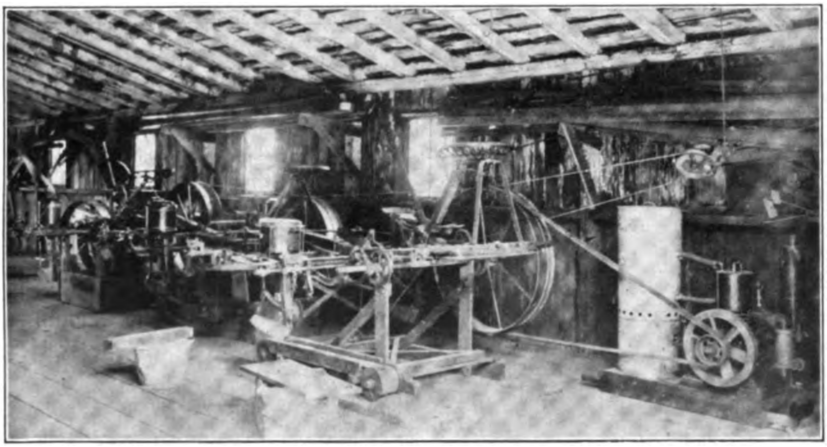
It is of value in connection with this work in that it furnishes something of a foundation to work upon, something of an idea of the value of having corn and planters that will give an accurate drop and place each kernel in the ground exactly where it should be with respect to the other kernels, the surface of the ground, the moisture in the ground, the soil particles, etc. It is evident that this is not as important as it is generally supposed, the essential thing being to place the seed in moist ground with the soil firmly packed about it.

The corn for this experiment was taken from the general stock of seed corn of the Experiment Station Farm. The ears were taken as they came, that is, without any selection. Before shelling, the ears were divided into three grades, as follows: Those with very long kernels, those with kernels of medium length, and those with very short kernels. After this selection was made the ears were all butted and tipped, with the butt and tip kernels carefully reserved according to grade, weights being taken of each grade. The remaining corn was shelled and each grade weighed.

It is necessary to have the weights of each grade to know what per cent of the entire seed can be put into each particular grade. This of course is the important thing that the seed corn producer wishes to know. If the planter will plant a certain grade better than another or better than it would if it had not been graded at all, will it pay to sacrifice the otherwise good seed which the grading or grader has thrown out?

Four different kinds of drop were used and three different makes of planters. One of the planters was equipped with both the accumulative and full-hill drops. In both cases it was equipped with the round-hole planter plate. The other two planters had the edge-selection plate, but one had a continuous plate movement, the other intermittent. An accumulative-inter mittent drop can be understood to be one where the hill is accumulated by having each cell in the planter plate deposit one kernel in the dropping tube as it passes, three cells to pass if it is set to plant three kernels to the hill, when the plate stops moving until the check wire throws the clutch on the dropping shaft again.

The planters were mounted on standards, one just ahead of the other, as shown in the cut. A small endless cotton rope with a single loop knot every three feet and six inches and with washers threaded into the rope, one in front of each knot, was looped around the right-hand planter wheel of each planter, thru an idler pulley at the front, back thru the check-heads of the planters just as the check wire would go in the field and thru another idler pulley at the rear. A small gasoline engine was belted to the right-hand rear planter wheel and timed to make the



This cut shows the planters as they were set up for making the tests. The small rope passing thru the idler pulley over the engine is looped once about each planter wheel thru an idler pulley at the other end and back thru the check-heads of the planters. This rope has knots every three feet and six inches which act as the buttons on a check wire. The left planter wheels have been removed to make it easier to count the hills as they are dropped.

engine belt run at the rate of a little less than two and one-half miles per hour. It is readily seen that we have very nearly the same conditions which we would have in the field. Here we have the check wire moving instead of the planter. In the field this is reversed of course. Endless belt conveyors carried the kernels away from the planter shoe as they were dropped.

Preliminary tests of about one hundred hills were made with each kind of drop and each grade of corn to find which planter plate was best suited to each particular grade of corn. With the preliminary tests made and everything in readiness, a test of each of the three different grades of corn previously prepared was made in the following manner:

The engine was made to run the planters at the ordinary rate which they would run when working in the field. The endless rope was placed in the check-head of each planter in turn as the tests were made. This caused only one planter to drop at a time. One person sat at the rear of the planter shoe to count the kernels dropped for each hill as they came from the planter, another sat nearby and recorded the number as it was called out. The kernels dropped for one thousand or more hills were counted for each planter with each grade of corn, or in other words 4,000 hills were dropped and counted for each grade of corn. With one planter having the two kinds of drop the tests were duplicated, using each kind of drop in turn.

When the tests for the three grades were completed, this corn was all put together, giving us seed corn from which the butt and tip kernels had been removed. A test of this grade of seed was made on each of the four kinds of drop as before.

Another grade was obtained by putting these middle kernels thru the grader. That is, it gave us seed which was machine graded, butted and tipped. A test was made of this.

After these tests the butt and tip kernels and those which had been taken out by the grader were mixed with the rest and we had our seed as it would have been had we shelled it from the whole ear. This was called "ungraded seed." A test was made as before.

The corn was then graded with one of the cylinder type of corn graders and weights were taken to show what part of the corn was removed in grading, and a test was made of the graded corn.

It was evident at the time that putting the corn thru the grader once did not grade it perfectly and it was decided to regrade the graded corn. A little more than half of the original corn was graded out by this time. This grade was tested.

The results obtained in the tests of the eight grades of corn and the four kinds of drops, comprising a count of 32,000 hills of corn, are recorded in the following table:

Table 1.—*Tests of graded corn and corn planters.*

Seed used	Planter	Plate	Per cent of hills having the number of kernels per hill shown (0 to 7)								Average number kernels per hill
			0	1	2	3	4	5	6	7	
Ungraded.	No. 1.......	A251	0.0	0.7	6.9	59.9	27.3	5.0	0.2	0.0	3.296
	No. 2.......	Small	0.0	2.4	17.2	65.8	13.5	1.1	0.0	0.0	2.937
	3, full hill..	414	0.0	1.2	19.5	56.7	21.3	1.3	0.0	0.0	3.020
	3, acc. drop.	9-16	0.0	5.6	27.0	45.2	19.5	2.5	0.2	0.0	2.869
Machine graded.	No. 1.......	A243	0.0	1.3	14.1	64.2	18.5	1.8	0.1	0.0	3.057
	No. 2.......	Small	0.0	1.7	18.1	68.0	11.4	0.8	0.0	0.0	2.915
	3, full hill..	414	0.6	1.2	14.9	57.8	24.4	1.1	0.0	0.0	3.075
	3, acc. drop.	17-32	0.2	7.7	34.4	44.6	11.4	1.7	0.0	0.0	2.644
Hand graded, butted, and tipped (long kernels).	No. 1......	A243	0.0	0.4	8.6	70.0	18.4	2.5	0.1	0.0	3.143
	No. 2.......	Medium	0.0	1.5	17.1	68.4	12.3	0.7	0.0	0.0	2.936
	3, full hill..	414	0.2	2.3	28.5	51.0	16.6	1.4	0.0	0.0	2.855
	3, acc. drop.	9-16	1.6	11.7	34.3	43.0	8.4	0.9	0.0	0.1	2.480
Hand graded, butted, and tipped (medium kernels).	No. 1.......	A251	0.0	1.2	15.4	63.6	17.7	2.1	0.0	0.0	3.041
	No. 2.......	Small	0.0	0.1	6.5	69.1	21.7	2.6	0.0	0.0	3.201
	3, full hill..	414	0.1	0.2	6.9	52.8	36.4	3.4	0.2	0.0	3.361
	3, acc. drop.	9-16	0.1	4.0	22.8	57.2	15.1	1.7	0.0	0.1	2.866
Hand graded, butted, and tipped (short kernels).	No. 1.......	A251	0.0	0.1	1.4	58.7	31.3	7.5	1.0	0.0	3.477
	No. 2.......	Small	0.0	0.0	3.7	60.3	29.2	6.5	0.3	0.0	3.394
	3, full hill..	....	0.0	2.0	22.7	59.3	15.9	0.1	0.0	0.0	2.894
	3, acc. drop.	17-32	0.1	1.7	16.5	56.5	21.6	3.4	0.2	0.0	3.089
Ungraded, butted, and tipped	No. 1.......	A251	0.1	1.0	8.9	62.6	23.9	3.3	0.2	0.0	3.199
	No. 2.......	Small	0.0	2.0	14.9	64.5	17.6	1.0	0.0	0.0	3.006
	3, full hill..	414	0.0	0.3	8.3	50.4	37.4	3.4	0.2	0.0	3.355
	3, acc. drop.	9-16	0.0	5.1	24.0	52.2	16.1	2.3	0.3	0.0	2.875

raded, butted, and	No. 1…….	A251	0.0	0.15	3.7	67.2	25.1	3.9	0.0	0.0	3.289
	No. 2…….	Small	0.0	0.0	6.4	67.0	23.3	3.2	0.1	0.0	3.275
	3, full hill..	840	1.1	4.0	37.8	51.0	6.0	0.1	0.0	0.0	2.570
	3, acc. drop.	17-32	0.0	8.6	28.5	53.5	8.9	0.5	0.0	0.0	2.643
hine graded.	No. 1…….	A243	0.0	0.2	8.0	70.6	19.0	2.1	0.1	0.0	3.151
	No. 2. ..	Small	0.0	0.4	11.2	63.3	23.3	1.8	0.0	0.0	3.143
	3, full hill..	414	0.0	0.2	7.3	58.5	30.3	3.5	0.2	0.0	3 302
	3, acc. drop.	9-16	0.2	4.5	25.9	55.9	12.3	1.1	0.1	0.0	2 793

A study of the above table will show the following points of interest:

1. Planter No. 2, which has an accumulative-continuous plate movement edge-selection drop, did not make a single hill out of its 8,000 without at least one or more kernels in it. Neither did it drop a hill with as many as seven kernels and in only one instance did it put as many as six kernels to a hill.

2. In every instance except one the edge-selection plates or planters, Nos. 1 and 2, gave a more nearly perfect drop than the round-hole plates gave.

3. The most perfect drop obtained was with the "twice machine graded" corn and the edge-selection-intermittent drop of planter No. 1.

4. The poorest drop was with the "hand graded, butted, and tipped (long kernels)" and the round-hole plate and accumulative drop. The number of hills in this test having two kernels was large, there being 343 out of the 1,000 hills counted, which indicates that the plate used was too small. Poor results were also obtained with this drop using machine graded corn, but this test indicates, as the other one does, that the plate was too small. Apparently the poorest work done, then, was with the ungraded corn and this planter, as shown in the fourth line of figures in the table.

To compare the round-hole with the edge-selection plate the following figures taken from the preceding table are given:

Table 2.—***Round-hole vs. edge-selection planter plates, showing per cent perfect drop obtained with different planters and grades of corn.***

Seed used	Edge-selection		Round-hole	
	Planter No. 1, intermittent plate movement, accumulative drop	Planter No 2, continuous plate movement, accumulative drop	Planter No. 3, intermittent plate movement, full hill drop	Planter No. 3, intermittent plate movement, accumulative drop
Ungraded....	59.9	65.8	56.7	45.2
Machine graded	64.2	68.0	57.8	44.6
Hand graded, butted, and tipped (long kernels	70.0	68.4	51.0	43.0
Hand graded, butted, and tipped (medium kernels)............ .	63.6	69.1	52.8	57.2
Hand graded, butted, and tipped (short kernels)...............	58.7	60.3	59.3	56.5
Ungraded, butted, and tipped	62.6	64.5	50.4	52.3
Machine graded, butted, and tipped............	67.2	67.0	51.0	53.5
Twice machine graded....	70.6	63.3	58.5	55.9
Average for each kind of drop....	64.6	65.8	54.6	51.0
Average for each kind of plate................	65.2		52.8	
Difference in favor of edge-selection plate	12.4 (per cent)			

Every corn grower and seed corn producer is anxious to know whether it pays to grade seed corn. The following table shows the amount of seed sacrificed and the more accurate drop obtained as a result of grading, and represents a count of 32,000 hills, which is the number of hills on nine acres with hills three feet and six inches apart, each way.

TABLE 3.—*Showing in per cent the portion of seed corn remaining after it has been graded in different ways and the accuracy of the drop from the grades thus obtained.*

Seed used	Pounds of corn			Per cent of entire corn	Per cent of perfect drop	Average number of kernels per hill	Number of kernels per acre (10,668 correct)
	Before grading	Butts and tips	After grading				
Ungraded	......	......	......	100	56.9	3.031	10,770
Machine graded	40*	......	27½	69	58.6	2.923	10,400
Hand graded, butted, and tipped (long kernels)	40	2¼	5¼	16	58.1	2.853	10,130
Hand graded, butted, and tipped (medium kernels)	40	7	14½	36	60.4	3.117	11,070
Hand graded, buttod, and tipped (short kernels)	40	3½	7½	19	58.7	3.214	11,420
Ungraded, butted, and tipped	40	12¾	......	78	57.4	3.109	11,070
Machine graded, butted, and tipped	29¼	12¾	17½	44	59.7	2.944	10,460
Twice machine graded	......	......	......	50†	62.1	3.097	11,000

* These weights were not exactly as given; a few of the kernels being cracked in going thru the planters were graded out. They are given this way for comparison and the proportion is correct.

† The weights of this grade were misplaced, but it was known to be about half the original amount of corn.

We see by this table that it is better to grade the corn the second time with the grader than it is to butt and tip it and then grade it, a more accurate drop being obtained with the twice machine-graded than with the single grading and removal of butt and tip kernels, while the former did not remove as large a portion of the seed.

A study of the table shows also that it does not pay to separate the seed corn into the different lengths of kernels as was done in this experiment. Only a slightly better drop was obtained, at a sacrifice of a large portion of the seed.

It is shown that there is no relation between the accuracy of drop and the total number of kernels per acre. The poorest drop of any was obtained with the ungraded corn and came the nearest to having the required number of kernels per acre, or the nearest to three kernels to the hill.

Five and two-tenths per cent more perfect drop was obtained with the carefully graded corn than with corn not graded at all. Considering the fact that the replies to our letter based on actual experiments and experience show little importance in having the exact number of kernels per hill, there would be some question as to the benefit derived from the grading of corn. We are not ready, however, to advise farmers to discard their corn graders. We know a more accurate drop is obtained from carefully graded corn. When the corn specialist shows conclusively that there is nothing gained by having a specified number of kernels to each hill providing there is at least one and not more than six in a hill and the right number to the acre, we will be ready to do away with the corn grader.

Acknowledgment is due W. P. Jeffords, who as a student worked with C. F. Chase in preparing the apparatus and conducting the tests.

SOIL MULCH

By H. J. Young

During the past two or three years the soil mulch has received considerable attention. Especially during the dry season of the past year did we hear of the great need of the soil mulch in conserving soil moisture. In 1910 an experiment was started to determine the efficiency of the loose soil mulch, as compared with the hard, bare surface, in retarding the evaporation of soil water. The experiment was extended to include a comparison of the soil water that was lost thru transpiration from the leaf surface of vegetation as compared with the evaporation from the mulched or unmulched soil.

Three plots were selected, one of which was hoed to the depth of two inches. The second was scraped in order to keep all vegetation down, but the surface was left as free from loose soil as possible. The third plot was allowed to grow up to volunteer vegetation.

In 1911 the experiment was repeated. The soil mulch, however, instead of being made with a hoe, was made by the use of a garden plow. This method insured a more uniform depth of mulch and caused a much better pulverization of the soil.

In preparing the following tables the data have been selected for dates as nearly alike as possible for the two years. Also, instead of averaging the results for the two years, they are tabulated separately for comparison and to show the efficiency of the mulch in the two years. All percentages are based upon the

TABLE 1.—*Water in soil of cultivated plot.*

Depth	June 13, 1910	June 16, 1911	June 28, 1910	June 28, 1911	July 13, 1910	July 14, 1911	Aug. 13, 1910	Aug. 18, 1911	Sept. 2, 1910	Aug. 30, 1911	Sept. 15, 1910	Sept. 13, 1911
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	28.8	19.1	25.4	24.10	27.3	22.80	23.5	23.10	32.4	22.6	26.3	25.3
2	27.9	27.3	27.1	26.30	28.3	27.00	27.8	23.70	30.4	24.6	28.5	26.3
3	23.8	24.1	24.3	23.05	25.1	23.60	25.1	22.05	26.9	22.1	27.1	26.1
4	23.2	25.1	25.1	24.40	23.2	24.05	25.4	23.05	25.2	22.9	25.6	22.7
5	29.4	26.8	25.8	25.90	26.2	25.90	26.8	25.90	26.6	25.4	27.8	24.9
6	29.3	26.2	26.1	27.10	27.3	26.20	27.6	26.40	29.5	25.1	29.5	25.2
Av.	27.0	24.7	25.6	25.20	26.2	24.90	26.0	24.00	28.5	23.8	27.4	25.1

It will be noticed from the above table that the per cent of moisture changes but little during the entire season. The first foot, however, fluctuates more or less, due to rains. This moisture which has been evaporated from the upper six inches does not concern us so much at this time, as we are dealing with the moisture that is well established in the soil. In the second foot of soil in 1910, eliminating the data for September 2 (which are for samples taken a few days after an 8-inch rain and consequently very high), there is a variation of only 1.4 per cent in the moisture content. In the same foot in 1911 there was a variation of only 3.6 per cent. In the sixth foot in 1910 the variation was 3.4 per cent, and in 1911 2 per cent. Comparing the averages of the six feet, which does away with the small fluctuations, the moisture content of the entire plot during 1910 varied 2.9 per cent, and in 1911 it varied 1.4 per cent.

This does not mean that there was only 2.9 per cent of water evaporated from the plot in 1910 or 1.4 per cent in 1911, but only

physical conditions of the soil, the mulch is not made in actual farm practice, until a large per cent of the water from such rains has evaporated.

TABLE 2.—*Water in soil of scraped plot.*

Depth	June 13, 1910	June 16, 1911	June 28, 1910	June 28, 1911	July 13, 1910	July 14, 1911	Aug. 13, 1910	Aug. 18, 1911	Sept. 2, 1910	Aug. 30, 1911	Sept. 15, 1910	Sept. 13, 1911
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	30.3	26.8	25.4	20.30	26.8	19.20	23.8	21.6	30.5	20.3	27.3	23.9
2	27.8	30.4	26.5	24.50	26.6	25.30	27.3	23.8	29.9	23.8	28.3	26.0
3	25.4	26.0	24.4	22.40	24.5	22.20	23.0	21.7	27.3	21.3	26.3	23.9
4	25.3	26.1	24.0	23.05	23.3	23.05	23.8	22.3	27.1	20.5	26.2	25.1
5	27.6	27.8	26.4	25.00	26.1	24.60	25.1	24.9	29.6	23.3	27.9	24.1
6	27.1	28.0	27.2	25.50	27.4	24.70	26.1	25.4	32.4	24.4	29.2	26.7
Av.	27.2	27.5	25.6	23.40	25.6	23.20	24.8	23.3	29.4	22.1	27.5	24.

In considering the data for the scraped plot it will be noticed that, due to rainfalls, the first foot fluctuates, as did the first foot of the cultivated plot. Comparing the data for this plot as we did those for the cultivated plot, we find a variation of 1.8 per cent in the second foot for 1910 and of 6.6 per cent in 1911. The sixth foot shows a variation of 3.1 per cent in 1910 and of 3.6 per cent in 1911. The variation in the average of the six feet in 1910 was 4.6 per cent and in 1911 5.4 per cent.

While this is a greater variation than was found in the cultivated plot, there is only 2.85 per cent difference, showing that the plot with the loose soil mulch was able to keep the moisture content 2.85 per cent nearer a constant during the season. It must be remembered that the weather conditions were such that the scraped plot during dry periods dried down to a depth of about two or three inches, and this dry layer appears to be almost as effective as the loose soil mulch. In all probability, if conditions had been such that a dry layer had not formed, the loose soil mulch would have shown a greater efficiency.

TABLE 3.—*Water in soil of untreated plot.*

Depth	June 13, 1910	June 16, 1911	June 28, 1910	June 28, 1911	July 13, 1910	July 14, 1911	Aug. 13. 1910	Aug. 18, 1911	Sept. 2, 1910	Aug. 30, 1911	Sept. 15, 1910	Sept. 13, 1911
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	29.00	26.8	14.5	13.9	19.8	11.9	13.4	19.6	32.80	12.8	27.90	16.2
2	25.80	28.4	21.0	21.2	19.2	14.8	18.2	16.0	30.25	15.0	30.20	14.2
3	24.10	24.5	24.6	20.0	20.4	15.3	16.6	14.1	27.80	13.5	25.80	15.9
4	25.10	27.5	25.3	24.0	25.4	20.4	16.9	13.4	26.10	13.8	24.10	14.8
5	25.50	27.0	25.3	27.4	26.5	26.8	19.1	15.0	23.10	16.8	20.60	20.8
6	27.05	27.1	26.7	25.8	27.3	26.7	25.3	20.2	24.70	18.7	24.75	18.1
Av.	26.10	26.8	22.9	22.0	23.1	19.3	18.2	16.4	27.40	15.1	25.50	18.3

The data for the untreated plot for the two years agree closely. The vegetation each year reached a height of about six feet. The data also show that the weeds have greatly reduced the moisture content at all depths. As the results are very similar for the two years, and as the 1911 data were not influenced by any heavy rainfalls of the four months, a comparison is made for but the one year. This plot during the four months varied in its moisture content as follows:

	Per cent.
1 foot	14.0
2 feet	14.2
3 feet	13.0
4 feet	14.1
5 feet	12.4
6 feet	9.0

The average departure from the original moisture content during the period of growth was 11.7 per cent as compared with 1.4 per cent in the cultivated plot and 6.4 per cent in the scraped plot. Thus it is easily seen that the vegetation has reduced the moisture content considerably and it appears that the transpiration of water from the leaf surface is a greater factor than is evaporation from the soil surface.

Thus, in conclusion, it may be said that the data for the two years 1910 and 1911, under the weather conditions that prevailed. show:

1. That a loose soil mulch was not much more effective than an unmulched soil in retarding the evaporation of the moisture that is well established in the soil.

2. That if a hard layer of soil dries out to the depth of two or three inches, it will act in the capacity of a mulch.

3. That much more of the established soil water is lost thru transpiration from the leaf surface of plants than is lost by evaporation from the soil surface.

THE NITROGEN CONTENT OF SOME NEBRASKA SOILS

By F. J. Alway and E. S. Bishop

In the following tables are given data on the nitrogen content of soil samples from the four chief soil areas of Nebraska—the Loess, the Glacial Drift, the High Plains, and the Sand Hills. The nitrogen content of the surface six inches varies from .306 to .018 per cent. Some of the samples of low nitrogen content are from unproductive soils, while others low in nitrogen are from soils of long-maintained productivity. In forming an opinion as to the sufficiency of the supply of nitrogen in the surface soil, one must consider not only from what part of the state the sample is taken, but also the type of soil and its composition in the virgin condition. While the maintenance of an adequate nitrogen supply is the chief chemical problem of soil fertility in Nebraska, the character of the subsoil, the presence of alkali, the slope of the land, and the amount and distribution of the water available for crops may entirely overshadow in importance even the nitrogen supply. In general, little information of value can be obtained from the chemical analysis of samples of soil as ordinarily taken by those who send them to the Experiment Station. In all cases samples should be taken from different places in the field in such a way as to show the character of the different soil layers within the first five feet of the surface at each place, and along with the samples should be sent a description of the layers as observed by the man while taking the samples. Usually more information of practical value can be secured from the field examination with an ordinary soil auger in the hands of an experienced person than can be obtained by weeks of laboratory investigation of samples.

found in samples taken to the same depth and from the same field at various places in eastern Nebraska.

Four sets were taken from near Pawnee City. The first was from a virgin prairie of level upland loess, the next from one on a steep hillside, and having a soil of glacial drift—*till.* Adjacent to the latter was a field which had been under cultivation about 40 years without the application of manure or the growing of any leguminous crops. Five individual samples were taken from this with a view to obtaining those showing the extremes in the same field. In a blue-grass pasture within the limits of Pawnee City ten individual samples were taken, some from the level land in the valley and some from the valley slopes.

From a virgin prairie on loess soil near Genoa five individual samples were taken to a depth of six inches and a similar set was taken from an adjacent cornfield which had been continuously under cultivation for 30 years without the application of manure or the growing of any leguminous crop.

Another set of samples was taken from a small prairie field on the farm of Professor E. W. Hunt, near Syracuse. The field was on the side of a steep slope with only a small area at the base of the hill. Starting at the top of the hill eleven individual samples were taken at intervals of 30 feet. The nitrogen content was lowest at the steepest part of the slope and highest near the foot.

Table 1.—*Nitrogen content of individual soil samples from various parts of Nebraska.*

Series No. of soil sample	Near Pawnee City				Near Genoa		Near Syracuse
	Loess, prairie 1-12 ins.	Till, prairie 1-12 ins.	Till, cultivated field 1-12 ins.	Valley, pasture 1-6 ins.	Loess, prairie 1-6 ins.	Loess, cultivated field 1-6 ins.	Till, prairie 1-12 ins.
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	.294	.227	.176	.288	.224	.181	.185
2	.294	.233	.161	.260	.242	.187	.183
3	.290	.248	.193	.306	.258	.176	.214
4	.278	.250	.166	.278	.257	.181	.168
5	.292	.229	.118	.231	.251	.178	.214
6	....	....	....	.260	....	....	.184
7	....	....	....	.293	....	....	.196
8	....	....	....	.274	....	....	.224
9	....	....	....	.293	....	....	.222
10	....	....	....	.240	....	....	.228
11	....	....	....	....	....	....	.223
Average	.290	.237	.163	.272	.246	.181	.204
Highest...	.294	.250	.193	.306	.258	.187	.228
Lowest...	.278	.227	.161	.231	.224	.176	.168
Difference	016	.023	.032	.075	.034	.005	.060

ON THE LOESS AREA

In Lancaster County.—Soils Nos. 1776 to 1789 (see Table 2) were taken from four fields in the Salt Creek Valley, near Havelock, A and A′ being adjacent and B and B′ being adjacent. A and B were virgin prairies which had for many years been used for hay land and which had never been fertilized. A′ and B′ had been under cultivation for 20 and probably as long as 35 years, but their early history is not known. Both were so located that there was little probability of their ever having been manured. From each field two composite samples of the first six inches of soil were taken, using ten cores for each composite, and from each of three of these fields two composite samples of the first foot of soil were taken by means of an auger, combining five borings for each. In the case of the six-inch samples the weight of the cores was determined in order to show the relative compactness of the soil.

The difference in nitrogen between the prairie B and the cultivated field B′ was about the same for the foot section as for the six-inch section, indicating that the loss of nitrogen had been about the same for the second six inches as for the surface six inches. The samples from the prairie were, however, considerably lighter than those from the cultivated fields, showing that the soil was not as compact in the prairies as in the cultivated fields. Hence, in order to have had strictly comparable samples the depth to which these were taken should have been greater in the prairies than in the cultivated fields.

Soils Nos. 1790, 1791, and 1795 to 1801 inclusive were taken from two virgin prairies, the one near Tabitha Home, one mile south of the Experiment Station, and the other near Bethany. Samples to the same depth were taken from adjacent cultivated fields, both of which had been in cultivation for twenty years or more. Each sample analyzed was a composite of ten individual samples.

In October, 1908, nine composite samples were taken to a depth of six inches from the lowland portion of a field on the northeast corner of the Experiment Station Farm. The field was first plowed in 1892, and cropped with wheat and oats in 1893, 1894, and 1895, alfalfa being seeded with the oats in the last-mentioned year. From that time until it was plowed at the end of 1906 the field had been kept in alfalfa. The part from which the samples were taken was in corn in 1907 and 1908. At the time of sampling, the cornstalks had been removed and part of the field had been plowed. Each sample analyzed consisted of ten individual samples taken by means of a brass tube 1⅜ inches in diameter and provided with a brass collar 6 inches from the end. The tube was forced into the ground until the collar rested firmly on the surface. The individual samples used for each composite were taken at intervals of 30 feet in such a way as to represent an area of one-fifth of an acre.

From an adjacent pasture on virgin prairie two similar com-

It is evident from the analyses that to form a reliable estimate of the relative amounts of nitrogen in the cultivated field and in the pasture the composites analyzed should be made up of a large number of individual samples, ten being far too few. Unlike the hayfield mentioned above, the pasture had more compact soil than the unplowed portion of the adjacent cultivated field.

Nos. 1735 to 1738 were taken from a field of virgin prairie and an adjacent cultivated field on the hill just south of the penitentiary near Lincoln. The soil is a sandy loam, formed partly from the underlying Dakota sandstone but mixed more or less with loess. Each of the samples analyzed was a composite of ten individual samples. In the case of each of these fields the two composite samples gave entirely concordant results.

In May, 1908, samples of soil, Nos. 1606, 1607, and 1608, to a depth of six inches were taken from a field of wheat on loess soil east of Bethany. Part of the field consisted of a level hilltop. part of a steep hill slope, and part of a comparatively level stretch at the foot of the hill. The surface soil on the level hilltop and at the base of the hill were of the ordinary dark color, while that on the slope had a yellow color. The wheat on the slope was badly stunted and gave little promise of producing grain, while there was a good growth on the hilltop and a very rank growth at the foot of the slope.

Table 2.—*Nitrogen content of surface soils from near Lincoln.*

FIELDS IN SALT CREEK VALLEY.

Soil No.	Depth	Field	Nitrogen	Average weight of cores
	Inches		*Per cent*	*Grams*
1776	Surface six inches	A, Prairie	.250	121
1777	Surface six inches	A, Prairie	.240	129
1784	Surface six inches	B, Prairie	.225	124
1785	Surface six inches	B, Prairie	.223	115
1782	Surface foot	B, Prairie	.183	....
1783	Surface foot	B, Prairie	.191	....
1778	Surface six inches	A, Cultivated field	.196	152
1779	Surface six inches	A, Cultivated field	.194	154
1780	Surface foot	A, Cultivated field	.135	....
1781	Surface foot	A, Cultivated field	.130	....
1786	Surface six inches	B, Cultivated field	.195	135
1787	Surface six inches	B, Cultivated field	.194	134
1788	Surface foot	B, Cultivated field	.145	....
1789	Surface foot	B, Cultivated field	.150	....
FIELDS ON UPLAND NEAR EXPERIMENT STATION FARM.				
1790	Surface six inches	Prairie near Tabitha Home	.280	....
1791	Surface six inches	Prairie near Tabitha Home	.277	....
1792	Surface six inches	Prairie near Tabitha Home	.281	....
1794	Surface six inches	Adjacent cultivated field	.192	....
1795	Surface six inches	Prairie near Bethany	.240	....
1796	Surface six inches	Prairie near Bethany	.256	....
1797	Surface six inches	Prairie near Bethany	.285	....
1799	Surface six inches	Prairie near Bethany	.290	....
1801	Surface six inches	Prairie near Bethany	.241	....
1798	Surface six inches	Adjacent cultivated field	.196	....
1800	Surface six inches	Adjacent cultivated field	.210	....
FIELDS ON EXPERIMENT STATION FARM.				
1817	Surface six inches	Cornfield, plowed portion	.257	89
1818	Surface six inches	Cornfield, plowed portion	.271	90
18 9	Surface six inches	Cornfield, plowed portion	.274	91
1820	Surface six inches	Cornfield, unplowed portion	.256	124
1821	Surface six inches	Cornfield, unplowed portion	.245	121
1822	Surface six inches	Cornfield, unplowed portion	.259	115
1823	Surface six inches	Cornfield, unplowed portion	.260	101
1824	Surface six inches	Cornfield, unplowed portion	.275	117

TABLE 2.—*Nitrogen content of surface soils from near Lincoln—Concluded.*

FIELDS ON RESIDUAL SOIL FROM DAKOTA SANDSTONE.

Soil No.	Depth	Field	Nitrogen	Average weight of cores
	Inches		*Per cent*	*Grams*
1735	Surface six inches	Prairie	.132	....
1736	Surface six inches	Prairie	.133	....
1737	Surface six inches	Cultivated field	.097	....
1738	Surface six inches	Cultivated field	.097	....

WHEAT FIELD NEAR BETHANY.

Soil No.	Depth	Field	Nitrogen	Average weight of cores
1607	Surface six inches	From level hilltop	.199	....
1606	Surface six inches	From steep slope	.104	....
1608	Surface six inches	From foot of slope	.198	....

IN THE SAND HILLS

From the crests of sand hills near Dunning, Blaine county, the samples of soil reported in Table 3 were taken. The barest hills were purposely selected in order that the samples might be representative of the Nebraska surface soils lowest in nitrogen and humus. A much higher percentage of nitrogen and humus occurs in the surface soil of the basins and valleys of these sand hills.

TABLE 3.—*Composition of soil samples from sand hills, near Dunning.*

Soil No.	Depth	Humus	Humus ash	Nitrogen
		Per cent	*Per cent*	*Per cent*
771	Surface six inches	...	...	.027
774	Surface six inches	.16	.53	.025
775	Surface six inches	.18	.14	.024
777	Surface six inches	.14	.09	.018
772	First foot	...	...	.028
773	Second foot	...	...	.013
778	First foot	...	...	.024
779	Second foot	...	...	.013
780	Third foot	...	...	.007
784	First foot	...	...	.021
785	Second foot	...	...	.021
790	First foot	...	...	.014
791	Second foot	...	...	.006
796	First foot	...	...	.013
797	Second foot	...	...	.011

ON THE HIGH PLAINS

IN CHASE COUNTY.—On the High Plains in western and northern Nebraska there occur various types of soil, some as coarse as the dune sand reported in Table 3 and others as fine in texture as the soils from the western part of the loess area. These variations in texture are accompanied by corresponding variations in the nitrogen content, the finer the texture the higher being the nitrogen content of the surface soil of the virgin prairies.

The data on samples from near Imperial in Chase county, given in Table 4, illustrate the conditions on the western part of the High Plains in Nebraska. The surface soil of these two prairies a mile apart and both about three miles east of Imperial was sampled in inch sections. Ten cores were taken in one to a depth of 12 inches and ten in the other to a depth of 6 inches, and these subdivided. In the first prairie the soil was a very light sandy loam with a uniform, open, sandy subsoil to a depth of more than six feet, while the other was a very heavy loam with a heavy subsoil and with rock occurring at a depth of about three feet.

TABLE 4.—*Nitrogen in surface foot of prairies near Imperial.*

Depth	Sandy land	Hard land
Inches	*Per cent*	*Per cent*
1	.084	.162
2	.078	.128
3	.088	.140
4	.079	.125
5	.071	.104
6	.067	....
7	.062	....
8	.060	....
9	.054	....
10	.054	....
11	.057	....
12	.065	....
Average	.068	

Immediately adjoining the sandy prairie and having a similar

September 6, 1907, bore a good crop of corn. The owner of the farm, as well as the neighboring old settlers, considered this field one of the most productive in the county and thought that it had shown little or no appreciable decline in yield since it was first plowed. As it had been in corn nearly every year, it is probable that any marked change would have been recognized. The nitrogen content of the surface six inches of the cornfield was .054 per cent compared with .077 per cent in the prairie, a loss of .023 per cent. That this was about the usual loss under similar conditions is shown by the data in Table 5, the samples there reported being taken on the same occasion from various fields near Imperial. In each case the prairie sampled was immediately adjacent to the cultivated field with which it is compared and had the same type of surface soil. The nitrogen content of the prairies varied by more than 50 per cent, those high in nitrogen being on "hard land" and those low in nitrogen on sandy land.

TABLE 5.—*Losses of soil nitrogen caused by cultivation on the High Plains, near Imperial.*

Field	Years in cultivation	Depth of sample	Nitrogen		
			In cultivated field	In adjacent prairie	Loss
		Inches	*Per cent*	*Per cent*	*Per cent*
A	21	Surface six inches	.085	.103	.018
A	21	Second six inches	.070	.110	.040
B	21	Surface six inches	.108	.143	.035
B	21	Second six inches	.070	.107	.037
C	21	Surface six inches	.067	.093	.026
D	21	Surface six inches	.054	.080	.026
E	20	Surface six inches	.117	.137	.020
F	21	Surface six inches	.078	.103	.025
G	12	Surface six inches	.074	.099	.025
H	10	Surface six inches	.093	.105	.012
H	10	Second six inches	.053	.074	.021

position but to their openness of texture, permitting the rains to quickly penetrate so deeply into the subsoil that little water is lost by evaporation. This was well shown at the time the fields mentioned in Table 4 were sampled. Between August 1 and 25 only 1.02 inches of rain had fallen, while between August 26 and September 6 3.52 inches had fallen. The examination of the fields on September 6 showed that the prairies on "hard land" had been moistened to a depth of only about 18 inches, while the sandy prairie and the adjacent cornfield were moist to a depth of more than six feet. The following autumn, winter, and spring were unusually dry, the total precipitation at Imperial between September 6, 1908, and May 4, 1909, amounting to only 3.88 inches. It is probable that most of the moisture found in the surface 18 inches of the "hard land" early in September had evaporated before May but that a large proportion of that in the subsoil of the sandy prairie was carried over.

Some of the conditions on the more humid portion of the High Plains are illustrated by the data given in Table 6, on samples taken from a farm near the eastern edge of Holt county. The soil of the farm is a light sandy loam. On part of it corn had been grown continuously for about 25 years without the application of barnyard manure or the growing of leguminous crops. Most of the field still produced a fair crop of grain but on a number of small areas the corn had practically ceased to produce any ears. The stalks on these areas year after year made a weakly growth, becoming about half as tall as on the rest of the field, tasseled and put forth ears, but failed to form any appreciable quantity of seed. Samples Nos. 1724 and 1733 were taken as representative of the surface soil of the main portion of the field and samples 1723 and 1725 as representative of that of the unproductive portions. Samples Nos. 1723 and 1726 were taken to the same depth from an adjacent virgin prairie. Each six-inch sample analyzed was a composite of five individual samples and the foot samples were composites from two borings. The percentages of nitrogen in the prairie, the productive, and the non-productive soils were approximately .160, .120, and .050, respectively.

TABLE 6.—*Nitrogen in soil of a farm near Page, Nebraska.*

Soil No.	Depth of sample	Fields	Nitrogen
			Per cent
1726	Surface six inches	Virgin prairie	.169
1734	Surface six inches	Virgin prairie	159
1724	Surface six inches	Long cultivated, but still productive, soil	.117
1733	Surface six inches	Long cultivated, but still productive, soil	.112
1723	Surface six inches	Long cultivated, unproductive soil	.040
1725	Surface six inches	Long cultivated, unproductive soil	.063
1727	First foot	Virgin prairie	.132
1728	Second foot	Virgin prairie	.070
1729	Third foot	Virgin prairie	.034
1730	Fourth foot	Virgin prairie	.024
1731	Fifth foot	Virgin prairie	.023
1732	Sixth foot	Virgin prairie	.022

ON THE GLACIAL DRIFT

In October, 1908, a farm near Syracuse was visited which presented many soil problems. The most of it was brought under cultivation over 50 years ago, and until it was secured by Professor E. W. Hunt some 15 years ago it had been farmed in the most shiftless manner. The plowed land had been kept continuously under cultivation without manure and without the growing of leguminous crops. Most of the farm is hilly and from various parts of it so much of the surface soil had been washed off and blown off that some of the fields had been abandoned. Professor Hunt, by the use of barnyard manure, the growing of leguminous crops, and deep plowing, had made the farm as a whole productive but some small areas still failed to give satisfactory returns.

While in general on such a farm as this the nitrogen problem is the most important, there are so many other problems that in trying to remedy defects every unproductive area has to be considered separately. The data given below indicate how little information is furnished by the nitrogen determinations alone.

The nitrogen content of the surface soil and subsoil of the prairie is shown in Table 7. The first six-inch sample was taken from near the top and the other two from the foot of the hill.

Near this prairie was a cornfield on most of which was a fair crop but on one spot near the center the corn was a complete failure. On this small area crops had been a failure year after year. The stalks reached a height of only a foot and a half to three feet and formed little or no grain. Surrounding this small area were thrifty plants six to seven feet tall and well eared. The nitrogen content of the surface six inches of the unproductive spot, .145 per cent, was low but not low enough to explain the condition of the corn. An examination by the auger, however, showed that the soil at a depth of only from 8 to 14 inches passed into the underlying soft shale, and so gradually that it was difficult to decide where the soil ceased and the rock began. Toward the edges of the area as the soil became deeper the corn improved. This was a case where nothing except an examination with the soil auger was needed in order to solve the problem. No remedy can well be applied to such an unproductive spot and the best thing to be done with it is to seed it to a grass that is adapted to shallow, fine-textured soils.

In an adjacent clover field there were a number of comparatively unproductive spots on which the soil was lighter in color than on the remaining productive portion of the field. The nitrogen content of the former was .158 per cent and of the latter .175 per cent. An examination of the subsoil of the unproductive spots and of the intervening productive land showed no appreciable difference in the texture to a depth of three feet. The difference in the nitrogen content of the surface soil is more apt to be a result of the nonproductivity than to be the cause of it, as a luxuriant growth of red clover was found on various exposed areas of subsoil. The cause of the nonproductivity remains an unsolved problem.

In another clover field there were a few small circular patches that were practically barren, neither clover nor weeds growing upon them. The nitrogen content of the surface six inches was found to be .153 per cent, while that of the soil taken at a distance of five feet, where there was a luxuriant growth of clover, was .190 per cent. The texture below the surface foot was similar to that under the clover. The surface six inches contained a little alkali, while the second six inches was heavily charged with it. The cause of the nonproductivity in this case was the presence of alkali.

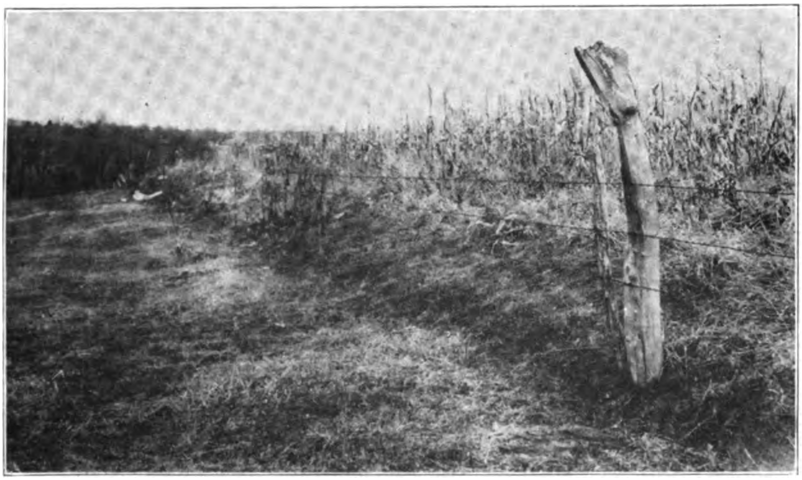
In another field of clover there were a number of spots on which the clover had been making an unsatisfactory growth. The nitrogen content of the surface six inches of soil on these was .192 per cent, while that of the surrounding soil was .196 per cent. An examination to a depth of three feet by means of an auger failed to disclose the cause of the poor growth and no appreciable quantity of alkali was found. This also remains an unsolved problem.

Several sets of samples were taken from a hillside in a corn field on which the crop was very uneven. This part of the field had all received the same treatment, but three distinct conditions were plainly to be distinguished. On the very gentle slope near the top of the hill there was a good stand of plants and the stalks had made a fair growth, but a third of them were barren and the others bore very small ears. On the steepest part of the hillside, below the above, the stand was very thin but there were few barren stalks and the ears were larger. At the foot of the hill there was a good stand of large stalks and nearly every one bore a good-sized ear. To express the crop conditions quantitatively, a bushel of ears was gathered from each of the three areas. The length of the rows from which they were gathered was measured and the number of stalks counted. From these data, assuming that one measured bushel of ears gives half a bushel of shelled corn, the estimates of yields given in Table 7 were made. Samples of soil from different depths—the first six inches, the second six inches, the second foot, and the third foot—were taken from each of the three areas from which the corn had just been gathered. The soil in the first two areas was very compact, while that in the third was mellow to a depth of two feet or more.

TABLE 7.—*Nitrogen content of soil on farm of Professor E. W. Hunt, near Syracuse, Nebraska.*

Depth	No. of individual samples used in composite	Cornfield					Prairie
		Thin stand	Few ears	Good crop	12 ft. from fence	On grassy terrace	
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Surface six inches, sample No. 1	10	.181	.203	.208	......	....	.228
Surface six inches, sample No. 2	10	.193	.215	.198	......	....	.242
Surface six inches, sample No. 3......	10	......	.201	.....	......	....	.226
Average.	10	.187	.206	.203	......	..... .	.232
Second six inches ...	5	.084	.099	.101	.. ...	......	.161
First foot............	5	.135	.153	.152	.175	.238	.204
Second foot.........	3	.064	.065	.093	.174	.152	086
Third foot...........	3	.038	.053	.063	.136	....	.056
No. of plants per acre	....	1476	5577	5830	.... .	... .	......
No. of ears per acre..	....	1352	3900	5724	......	....	......
Bushels per acre....	....	9	20	53	......	....	. ....

The nitrogen content was somewhat the lowest in the area with the thinnest stand, but in the surface soil there was practically no difference between the area giving a yield of 20 bushels per acre and that giving 53 bushels. The subsoil of the latter was richer in nitrogen, this being due to the accumulation of surface soil washed from the hillside. That much of the surface soil from the hillside had been washed down and deposited at the foot of the slope is shown in the figure in which may be seen a terrace at the edge of the cornfield. This had been gradually built up above the original surface. The formation of the terrace within and above the fence, instead of below it, is to be attributed to the unplowed strip within the fence, covered with long grass and weeds, arresting the soil washed down from the slope. After each fresh deposit the vegetation would grow thru and upon it, thus firmly anchoring the new material in place and forming a barrier to arrest the material brought down by the next heavy rain. Samples were taken on both this grassy terrace. at a distance of three feet from the fence, and from the cornfield at a distance of twelve feet. In the case of the latter the soil was black and mellow to a depth of thirty inches.



A terrace formed at the foot of a slope which had been in cultivation 50 years. The original level of the surface is shown by the grass at the left.

No alkali was found in the subsoil.

The comparatively unproductive areas suffered more from the compactness of their soil than from any lack of nitrogen. Deep plowing, by rendering the soil more open and thus checking the erosion and permitting more water to enter the subsoil, as well as facilitating the deeper penetration of plant roots, would evidently improve conditions. Very deep plowing, Professor Hunt informs us, has since greatly improved the conditions on this hillside.

Thus, on the slopes of this one hilly farm the unproductivity is found to be due in some places to lack of depth of soil, in others to the presence of alkali, in others to too great a compactness of the soil, and in still other places to causes not explained. In not one of these instances would the analysis of the surface soil have indicated the cause of the difficulty.

THE RELATIVE AMOUNTS OF NITROGEN, CARBON, AND HUMUS IN SOME NEBRASKA SOILS

By F. J. Alway and C. E. Vail

The black surface soil of the loess prairies of Nebraska differs from the yellow or gray subsoil chiefly in the proportion of organic matter and in the physical properties as affected by this organic matter. The total organic matter of soils, including all the material of vegetable and animal origin, may be roughly divided into two parts, each consisting of a mixture of many, but, as yet, almost altogether unknown, compounds. The one part, designated as *humus,* is soluble in dilute alkalies and may, after preliminary treatment of the soil with dilute acid, be leached out with an ammonia solution, while the other part, the unhumified organic matter, remains undissolved. Each of these two parts of the organic matter in the soil contains an important part of the soil nitrogen and each exerts an important influence on the physical properties of the soil, but the influence of the humus appears to be much greater than that of the unhumified organic matter. Probably the most important chemical function that each serves is as a source of nitrogen for growing plants, but neither is necessary for normal plant growth, provided that available nitrogen is supplied, as in the form of nitrates or of ammonium salts. The relative availability of the nitrogen in the two forms is a much disputed question but it is universally recognized that both are at least ultimate sources of available nitrogen.

The methods of chemical analysis employed in the determination of these three constituents—nitrogen, humus, and unhumified organic matter—differ much in the time required for their performance and in the accuracy and the reliability of the results.

The nitrogen of soils is regularly determined by chemists by the Kjeldahl method, which is both accurate and rapid of execu tion. Where duplicate determinations of nitrogen are made by this method by a moderately experienced analyst and these are concordant, the results are to be regarded as both accurate and reliable.

The methods for the determination of humus are, up to the present time, in an extremely unsatisfactory condition, as is illustrated by the fact that the method still recognized as "official"—that adopted by the Association of Official Agricultural Chemists of the United States—gives results which are, in general, from 30 to 100 per cent too high. An exhaustive study of the different methods that have been proposed for the determination of humus was recently made at this Station,[1] as a result of which it was concluded that the Mooers-Hampton modification of the "official" method, and a somewhat altered form of the Cameron-Breazeale modification of the "official" method, as well as the Hilgard method, give accurate and reliable results. A very recent bulletin published by the Hawaii Agricultural Experiment Station[2] deals with the same subject but reports the failure of its authors to confirm the conclusions arrived at in this laboratory.

The determination of the unhumified organic matter is in an equally unsatisfactory condition for the reason that this constituent is not determined directly but is estimated by deducting the percentage of humus found from that of the total organic matter. Hence, any error in the determination of either total organic matter or humus causes a corresponding error in the determination of the unhumified organic matter. The determination of organic matter has been made by methods based upon either one of two different principles. In the one the soil, dried at 100° C. or 110° C., is ignited until no further loss in weight occurs; then the organic carbon and the estimation of the organic matter from this on the assumption that the carbon constitutes a certain definite part, usually considered to be 58 per cent. For the determination of the organic carbon three different methods have been employed, viz., (1) ignition of the soil, mixed with copper oxide, in a current of oxygen, (2) the oxidation of the soil with chromic acid solution, and (3) the combustion of the soil with sodium peroxide. The first method, which has been the basis of the remarkable development of organic chemistry during the past eighty years, is one permitting of great accuracy but is very time-consuming. The amount of time it requires is the objection that has prevented its universal use and which has caused the easier and more expeditious chromic acid method to be more generally employed. The latter, however, as it has been used, gives too low results on account of the incomplete oxidation of the organic matter.[3] Hall[4] has recently proposed a modification in the chromic acid method by which the oxidation is made complete so that as reliable results are to be obtained as by combustion with copper oxide. The sodium peroxide method[5] is of recent introduction and has had, up to the present time, a comparatively restricted use in soil analysis. As an indication of the concordance of the results obtained by the first two methods, the data in Table 1 are given.

TABLE 1.—*Organic matter in soils as found by different methods.*

Soil No.	Volatile matter	C × 1.724
	Per cent	*Per cent*
516	11.26	8.08
518	9.12	5.79
521	8.42	4.72
525	7.40	3.52
529	6.81	0.74

the humus, and the organic carbon. An error affecting the accuracy of the determination of one of the three will affect two of the ratios and if two of the determinations are erroneous all three ratios will be erroneous, unless it should happen that an error in the one determination should compensate for an error in another, and thus give the true ratios. In general, however, ratios based on the determination of humus by the "official" method or of carbon by the chromic acid method must be rejected.

We undertook the study, the results of which are presented in this article, to determine what constancy, if any, exists in the ratios of organic carbon to nitrogen, of organic carbon to humus, and of humus to nitrogen in samples of soil taken at different depths in the same field, from the same depth in different fields in the same locality, and from the same depth in fields of similar history but in different localities. The exhaustive study of the methods of humus determination referred to above had not been begun at the time that many of the determinations of humus were made and it was not completed until some time after the junior author* had left this Station. As a result, the humus determinations are not as accurate as they could now be made, in the light of our present knowledge. All the carbon determinations were made by the combustion method and are to be considered reliable. However, some of these may be inaccurate, as in order to shorten the time required and so increase the number of samples analyzed, duplicate determinations were made on only about one-fifth of the samples. This seemed justifiable in a preliminary study for the reason that in the hands of a skilled analyst but few carbon determinations are inaccurate, and a better idea of the general composition of the soils would be obtained than by the analysis of a smaller number, making duplicates of each. There is always the possibility, however, that in any particular determination there may be a leak in the apparatus, giving, as a consequence, too low a result for the carbon, and, accordingly, too low a carbon-nitrogen and carbon-humus ratio.

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* Since September, 1909, Mr. Vail has been on the faculty of the Colorado Agricultural College.

For the reasons thus detailed we consider the nitrogen determinations accurate, the carbon determinations accurate except possibly in a few unidentified instances, and the humus determinations in general only *comparatively* accurate. In cases where the ratios seemed either very high or very low, new humus determinations were made in duplicate or a duplicate carbon determination was made, but with a considerable number of the soils these irregularities and some important sources of error in the method of humus determination were not detected until all the soil samples had been used or had been combined to form composites, thus preventing a repetition of the analyses. Thus, for instance, the whole of the series of determinations of humus in the inch sections from the upland grove in Lancaster county have been omitted.

METHODS OF ANALYSIS

The nitrogen was determined in duplicate by the Kjeldahl method. The concordance of the duplicates is shown in Table 2.

The humus was determined by the Hilgard method, the 4 per cent ammonia solution being applied continuously to the soils, previously freed of lime and magnesia, until the washings were colorless. This usually required from 10 to 14 hours, according to the soil. This, as later found, is not sufficient for the complete extraction of the humus, for which 4 to 5 days' further treatment is required in the case of most of such soils.[8] The additional amount obtained by such continued treatment, however, is, in most cases, very small. A second source of possible error lies in the clay that is sometimes carried thru the filter in considerable quantities, with the result that too high a percentage of humus is found. Where the humus ash is determined, such an occurrence of clay in the humus extract is indicated by the accompanying high percentage of humus ash. In the earlier determinations the humus ash was not recorded but in all the later determinations it was recorded and it is reported in the accompanying tables. The reason we report the percentage of this so-called "humus ash" is that it serves as an indication of the reliability of the humus determinations. A third source of error lies in the solubility, in ammonia solution, of the glass of the bottles in which the humus extract was stored previous to the completion of the determination. As the first part of the analysis—that involving the removal of lime and magnesia, subsequent washing with distilled water, and the extraction with ammonia—could be made most economically where a large number of samples were being simultaneously extracted, we extracted from 50 to 100 samples at a time and stored the extracts in glass bottles until the solutions could be evaporated. As platinum dishes are necessary for this evaporation, only a few determinations could be made in one day. At times the platinum dishes had to be used for other analyses, increasing still further the time that the extracts were stored in the bottles before the analysis was finished. The bottles used, as was later found, were all unusually readily soluble in ammonia. The result was that on evaporation the compounds formed by the solution of the glass in ammonia remained behind and when ignited lost weight, like the clay referred to above. In Table 3 are given the data obtained with freshly prepared extracts and with those which had stood in the bottles for two months.

TABLE 2.—*Concordance of duplicate determinations.*

Soil No.	Nitrogen		Carbon		Humus	
	1	2	1	2	1	2
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
538	.189	.189	2.04	2.06	2.12	2.15
539	.192	.185	2.04	2.11	2.20	2.30
540	.161	.164	1.67	1.54	1.90	1.80
541	.189	.189	1.91	....	1.85	2.00
542	.193	.186	2 01	1.96	2.10	2.06
543	.186	.186	2.01	2.10	2.06	2.27
544	.200	.194	2.07	2.04	2.00	2.00
545	.198	.194	2.14	2.13	1.83	2.20

TABLE 3.—*Effect of storing humus extract in glass bottles.*

Soil No.	Fresh extract		Extract stored		Difference	
	Humus	Humus ash	Humus	Humus ash	Humus	Humus ash
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
731	2.61	1.39	3.08	2.64	.47	1.25
732	3.17	1.07	3.50	2.54	.33	1.47
733	2.35	.99	3.08	2.70	.73	1.71
734	1.65	1.02	2.10	2.42	.45	1.40
735	2.99	.99	3.44	2.20	.45	1.21
736	2.47	.62	3.21	2.28	.73	1.66
737	1.73	.43	2.28	2.15	.55	1.72
738	1.91	.61	2.59	2.31	.68	1.70
739	1.99	.91	2.43	2.52	.44	1.61
740	1.42	.65	2.00	2.04	.58	1.39

Where the percentage of ash had been recorded, the presence of dissolved glass was indicated by the high humus ash content. New determinations were made in the case of all those samples where it exceeded 1.50 per cent. It is probable that among the analyses the results of which have been retained there are errors from this source. While a considerable number of the humus determinations may be inaccurate, it is evident from the following instance that most of them should be considered reliable. In the case of a series of fourteen individual samples from Custer county, determinations of both humus and nitrogen were made. The results are given in Table 4. Later the remaining portions of these samples, which were all of about the same weight, were combined to form a composite which was used in the detailed study of the methods of humus determination already referred to. This soil is reported in Bulletin 115 as soil No. 2.[7] The humus in this as determined by the different reliable methods averaged 1.63 per cent, being 1.64 per cent by the Hilgard, 1.62 by the Cameron-Breazeale, and 1.63 by the Mooers-Hampton, while the average of the humus determinations on the individual samples was 1.62. The nitrogen content of the composite was 0.205 per cent.

TABLE 4.—*Composition of individual samples from a virgin prairie in Custer county.*

Sample No.	Humus	Humus ash	Total nitrogen	$\frac{\text{Humus}}{\text{N}}$ ratio
	Per cent	*Per cent*	*Per cent*	
1..........	1.57	.36	0.186	8.4
2..........	1.77	.50	0.228	7.8
3..........	1.58	.35	0.214	7.4
4..........	1.80	.41	0.227	8.0
5..........	1.49	.27	0.200	7.5
6..........	1.48	.39	0.193	7.7
7..........	1.33	.29	0.197	6.7
8..........	1.67	.31	0.205	8.1
9..........	2.00	.54	0.227	8.8
10..........	1.43	.29	0.202	7.1
11..........	1.68	.39	0.212	8.0
12........	1.87	.43	0.235	8.0
13........	1.44	.36	0.201	7.2
14........	1.53	.66	0.202	7.6
Average.	1.62	.40	0.209	7.8

The carbon was determined by combustion in oxygen, the carbonates present having been previously decomposed by means o phosphoric acid. The concordance of duplicate determinations smaller was employed to obtain the sample of the second foot. The larger auger was next used to enlarge the hole to the bottom of the second foot. Then by means of the small auger the third foot sample was taken. This process was continued for the still lower portions of the soil. The different foot samples analyzed were composites from two or more borings.

Nos. 528 and 529 were from a part of the campus of the Nebraska Wesleyan University which previous to 1889 had been part of a large pasture and which since that date had been mowed annually for hay. Occasionally the grass had been burned off in the spring.

Nos. 935 to 940 were taken by Mr. Robert Ashby from a lawn near Genoa. The native grasses of the prairie had been replaced by blue-grass.

Nos. 1459 to 1461 were from the upland portion, and Nos. 1462 to 1467 from the lowland portion, of a pasture field on the Experiment Station Farm. On this the native grasses have been crowded out but the field has never been plowed. The lowland portion of it is inundated at times by the overflow of Dead Man's Run but the soil regularly deposited at such times is soon covered by the grass which is able to grow thru it. The black soil which has thus gradually been formed now extends to a depth of from three to five feet. The upland portion of the field is above the reach of high water.

The samples reported in Table 6 are composites of from 10 to 12 cores taken to a depth of one foot with a 1⅜ inch brass tube. The cores were subdivided in the case of the first field into 10 and in the case of the other three fields into 12 parts. The first field, part of the Nebraska Wesleyan University campus, has been described above. Nos. 1491 to 1502 were from what is known as Peck's Grove, a few hundred yards south of the Experiment Station. Some 30 or 40 years ago cottonwood trees were planted in the prairie and since then the soil has been left undisturbed. A considerable amount of debris from leaves and branches had collected on the surface but this was removed before the samples were taken. Nos. 1469 to 1480 were from the lower portion of the same grove, this portion being flooded after torrential rains.

Nos. 1610 to 1621 are from a field on the farm of the Hon. George Coupland, near Elgin. Previous to 1878 this field was part of the unfenced prairie and since then has been used as pasture.

The samples reported in Table 7 are composites of six cores taken with a brass tube to a depth of 6 inches. All are from the Experiment Station Farm, two from the pasture field described above, one from the adjacent cottonwood grove, and nine from plots in the adjacent orchard. The plots in the orchard, as well as the adjacent field from which Nos. 546 and 547 were taken, are on the upland.

Table 8 gives the data on samples corresponding to those just described, but taken to a depth of one foot by means of an auger. Each sample was a composite from four borings.

The samples reported in Table 9 were from various fields near Elgin. They were taken by means of a brass tube to a depth of 6 inches and are composites of from six to ten cores. The prairies from which the first four samples were taken are not adjacent but are all within a radius of two miles.

Table 10 contains the data on samples taken from various parts of the state.

In all cases before taking a sample of surface soil the vegetation was cut off even with the surface, but all remaining organic matter, including the living roots, was dried and ground up with the soil for analysis.

TABLE 5.—*Samples from different depths of prairies.*

Soil No.	Depth	Nitrogen	Carbon	Humus	Humus ash	Ratios $\frac{C}{N}$	Ratios $\frac{Humus}{N}$	Ratios $\frac{C}{Humus}$
LANCASTER COUNTY, NEAR LINCOLN—UPLAND.								
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
*	First foot..	.240	2.82	2.69	....	11.7	11.2	1.0
528	Second foot	.111	.86	1.00	....	7.7	9.0	0.9
529	Third foot.	.066	.43	.45	....	6.5	6.8	0.9
NANCE COUNTY, NEAR GENOA—UPLAND.								
935	First foot.	.255	2.61	2.47	1.61	10.2	9.7	1.0
936	Second foot	.102	.85	1.00	.90	8.3	9.8	0.9
937	Third foot.	.056	.31	.40	.52	5.5	7.1	0.8
938	Fourth foot	.042	.24	.30	.64	5.7	7.1	0.8
939	Fifth foot.	.034	.17	.19	.33	5.0	5.6	0.9
940	Sixth foot.	027	.14	.16	.36	5.2	5.9	0.9
LANCASTER COUNTY, EXPERIMENT STATION FARM—UPLAND.								
1459	First foot..	.242	2.65	2.90	.88	11.0	12 0	0.9
1460	Second foot	.149	1.59	1.47	1.40	10.7	9.9	1.1
1461	Third foot.	.069	.68	.62	.42	9.9	9.1	1.1
LANCASTER COUNTY, EXPERIMENT STATION FARM—LOWLAND.								
1462	First foot..	.243	3.06	2.97	1.06	12.6	12.2	1.0
1463	Second foot	.191	2.39	2.36	.76	12.5	12.4	1.0
1464	Third foot.	.128	1.56	1.76	.80	12.2	13.8	0.9
1465	Fourth foot	.062	.62	.87	1.01	10.0	14.0	0.7
1466	Fifth foot..	.088	.64	.92	.34	7.3	10.5	0.7
1467	Sixth foot.	.073	.62	.68	.35	8.5	9.3	0.9

* Average of 516-525.

TABLE 6.—*Samples from different portions of the surface foot of prairies.*

LANCASTER COUNTY, NEAR LINCOLN—UPLAND.

Soil No.	Depth	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						$\frac{C}{N}$	$\frac{Humus}{N}$	$\frac{C}{Humus}$
		P. ct.	*P ct.*	*P. ct.*	*P. ct.*			
516	First tenth...	.347	4.69	4.20	......	13.5	12.1	1.1
517	Second tenth.	.295	3.60	3.45	....	12.2	11.7	1.0
518	Third tenth..	.269	3.36	2.97	......	12.5	11.0	1.1
519	Fourth tenth.	.251	2.92	2.81	....	11.6	11.2	1.1
520	Fifth tenth ..	234	2.78	2.85	....	11.9	12.2	1.0
521	Sixth tenth ..	.224	2.74	2.55	....	12.2	11.4	1.1
522	Seventh tenth	.197	2.31	2.22	....	11.7	11.3	1.0
523	Eighth tenth.	.184	2.19	2.27	....	11.9	12.3	1.0
524	Ninth tenth .	.177	2.06	2.20	....	11.6	12.4	0.9
525	Tenth tenth..	.173	2.04	1.72	....	11.8	9.9	1.2

LANCASTER COUNTY, LINCOLN—UPLAND—GROVE.

Soil No.	Depth	Nitrogen	Carbon	Humus	Humus ash	$\frac{C}{N}$	$\frac{Humus}{N}$	$\frac{C}{Humus}$
1491	First inch	.465	6.68	....	....	14.4	....	....
1492	Second inch..	.316	3.94	....	....	12.5	....	....
1493	Third inch...	.267	3.28	....	....	12.3	....	....
1494	Fourth inch .	.230	2.80	....	....	12.2	....	....
1495	Fifth inch ...	.230	2.59	....	....	11.3	....	....
1496	Sixth inch...	.209	2.29	....	....	11.0	....	....
1497	Seventh inch.	.192	2.01	....	....	10.5	....	....
1498	Eighth inch..	.194	1.84	....	....	9.5	....	....
1499	Ninth inch.	.185	1.80	....	....	9.7	....	....
1500	Tenth inch...	.184	1.63	....	....	8.9	....	....
1501	Eleventh inch	.163	1.54	....	....	9.4	....	....
1502	Twelfth inch	.161	1.54	....	....	9.5	....	....

LANCASTER COUNTY, LINCOLN—LOWLAND—GROVE.

Soil No.	Depth	Nitrogen	Carbon	Humus	Humus ash	$\frac{C}{N}$	$\frac{Humus}{N}$	$\frac{C}{Humus}$
1469	First inch....	.416	5.67	4.32	1.48	13.6	10.4	1.3
1470	Second inch..	.332	4.29	3.34	1.22	12.9	10.1	1.3
1471	Third inch...	.276	3.41	2.74	.50	12.4	9.9	1.2
1472	Fourth inch..	.235	2.92	2.45	.47	12.4	10.4	1.2
1473	Fifth inch...	.215	2.66	....	....	12.4	....	....
1474	Sixth inch...	.198	2.60	....	....	13.1	....	....
1475	Seventh inch.	.196	2.50	2.29	.58	12.7	11.7	1.1
1476	Eighth inch..	.190	2.33	2.25	.37	12.3	11.8	1.0
1477	Ninth inch...	.174	2.09	2.08	.21	12.0	11.9	1.0
1478	Tenth inch...	.167	1.92	1.82	.39	11.5	10.9	1.0
1479	Eleventh inch	.157	1.86	1.87	.33	11.9	11.9	1.0
1480	Twelfth inch.	.153	1.79	1.93	.32	11.7	12.6	0.9

Table 6.—*Samples from different portions of the surface foot of prairies—Concluded.*

ANTELOPE COUNTY, NEAR ELGIN—UPLAND.

Soil No.	Depth	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						$\frac{C}{N}$	$\frac{Humus}{N}$	$\frac{C}{Humus}$
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
1610	First inch...	.296	3.78	2.12	.60	12.8	7.2	1.8
1611	Second inch..	.263	3.26	2.16	.72	12.4	8.2	1.5
1612	Third inch...	.227	2.44	2.04	.44	10.7	9.0	1.2
1613	Fourth inch..	.205	2.41	1.68	.78	11.8	8.2	1.4
1614	Fifth inch....	.195	2.23	1.66	.68	11.4	8.5	1.3
1615	Sixth inch...	.192	2.05	1.64	.76	10.7	8.5	1.2
1616	Seventh inch.	.177	1.84	1.68	.58	10.4	9.5	1.1
1617	Eighth inch..	.161	1.69	1.64	.68	10.5	10.2	1.0
1618	Ninth inch...	.155	1.63	1.34	.68	10.5	8.6	1.2
1619	Tenth inch...	.149	1.41	1.28	.44	9.5	8.6	1.1
1620	Eleventh inch	.133	1.41	1.48	1.04	10.6	11.1	1.0
1621	Twelfth inch.	.128	1.27	1.00	.72	9.9	7.8	1.3

TABLE 7.—*Samples to a depth of six inches from different fields and plots on the Experiment Station Farm, Lincoln.*

UNPLOWED LAND.

Soil No.	Description of field or plot	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						C/N	Humus/N	C/Humus
		P ct.	*P ct.*	*P. ct.*	*P. ct.*			
534	Upland pasture...	.289	3.13	3 15	....	10.8	10.9	**1.0**
535	Lowland pasture..	.297	3 74	3.67	....	12.6	12.3	**1.0**
536	Lowland grove....	.293	3 52	3 40	...	12.0	11.6	**1.0**
	UNDER CULTIVATION 30 TO 40 YEARS.							
537	Cultivated crops 5 years, clover 2 years	.200	2.14	2.10	.45	10.7	10.5	**1.0**
538	Cultivated crops 5 years, alfalfa 2 years.	.189	2.05	2.05	.40	10.8	10.8	**1.0**
539	Cultivated crops 5 years, grasses 2 years.........	.188	2.07	2.25	....	11.0	12.0	**.9**
540	Clean cultivation 7 years....	.162	1.69	1.85	....	10.4	11.4	**.9**
541	Various cover crops 7 years...	.189	1.91	1.92	.48	10.1	10.2	1.0
542	Millet as cover crop 7 years....	.190	1.98	2.07	.30	10.4	10.9	**.9**
543	Oats 5 years, weeds as cover crop 2 years ...	.186	2.05	2.16	.40	11.0	11.3	1.0
544	Cultivated crops 5 years, litter mulch 2 years..	.197	2.06	2.00	.40	10.4	10.1	1.0
545	Various cover crops 7 years...	.196	2.13	2.01	.48	10.9	10.3	**1.0**
546	Alfalfa 11 years, corn 1 year.....	.252	2.54	2 56	.50	10.1	10.2	**1.0**
547	Alfalfa 12 years..	.235	2.44	2 67	.49	10.4	11 4	**.9**

TABLE 8.—*Samples to a depth of one foot from different fields and plots on or near the Experiment Station Farm, Lincoln.*

UNPLOWED LAND.

Soil No.	Description of field or plot	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						$\frac{C}{N}$	$\frac{Humus}{N}$	$\frac{C}{Humus}$
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
901	Upland pasture...	.233	2.68	2.29	.38	11.5	9.8	1.2
902	Lowland pasture..	.244	3.03	2.68	.43	12.4	11.0	1.1
903	Lowland grove...	.244	2.61	2.40	.60	10.7	9.8	1.1
	UNDER CULTIVATION 30 TO 40 YEARS.							
904	Cultivated crop 5 years, clover 2 years...........	.167	1.58	1.63	.18	9.5	9.8	1.0
905	Cultivated crop 5 years, alfalfa 2 years...........	.162	1.45	1.65	.34	8.9	10.2	0.9
906	Cultivated crop 5 years, grasses 2 years..	.161	1.45	1.39	.12	9.0	8.6	1.0
907	Clean cultivation 7 years.....	.143	1.24	.99	.23	8.7	6.9	1.2
908	Various cover crops 7 years...	.175	1.53	1.32	.24	8.7	7.5	1.2
909	Millet as cover crop 2 years....	.159	1.51	1.23	.26	9.5	7.7	1.2
910	Oats 5 years, weeds as cover crop 2 years ...	.172	1.62	1.30	.28	9.4	7.6	1.2
911	Cultivated crop 5 years, litter mulch 2 years..	.175	1.65	1.24	.26	9.4	7.1	1.3
912	Various cover crops 7 years...	.187	1.85	1.89	.38	9.9	10.1	1.0
913	Alfalfa 11 years, corn 1 year.....	210	2.13	1.77	.27	10.1	8.4	1.2
914	Alfalfa 12 years..	.214	2.07	1.85	.47	9.7	8.6	1.1
915	Alfalfa 1 year....	.193	......	1.80	.35	......	9.3	....
916	Alfalfa 1 year....	.216	......	1.91	.62	......	8.8	....
917	Alfalfa 1 year....	.210	......	1.88	.41	......	9.0	....

TABLE 9.—*Samples to a depth of six inches from different fields on the farms of the Hon. George Coupland and his neighbors, near Elgin.*

Soil No.	Description of field or plot	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						$\frac{C}{N}$	$\frac{Humus}{N}$	$\frac{C}{Humus}$
		P ct	*P. ct.*	*P. ct.*	*P. ct.*			
1622	Virgin prairie....	.242	2.92	2.17	.47	12.1	9.0	1.3
1637	Virgin prairie....	.214	2.40	1.65	48	11 2	7.7	1.5
1645	Virgin prairie....	.218	2.44	1.43	.64	11.2	6.6	1.7
1647	Virgin prairie...	.162	1.75	1.24	.46	10.8	7.7	1.5
1649	Cereal crops 31 years...........	.234	2.51	1.58	.76	10.7	6.7	1.6
1652	Cereal crops 22 years, alfalfa 5 years...........	.194	2.10	....	....	10.8	....	....
1654	Cereal crops 22 years, alfalfa 5 years.....	.178	2.15	1.60	.20	12.0	9.0	1.3
1657	Cereal crops 19 years, alfalfa 12 years........	.207	2.21	......	....	10.7	....	....
1632	Cereal crops 23 years, alfalfa 7 years...........	.197	1.96	1.64	.51	9.9	8.3	1.2
1634	Cereal crops 23 years, alfalfa 7 years...........	.166	1.70	1.36	.48	10.2	8.2	1.2
1635	Cereal crops 27 years...........	.171	1.78	1.40	.70	10 4	8.2	1.3
1636	Cereal crops 27 years...........	.163	1.67	1.38	.74	10.2	8.5	1.2
1641	Cereal crops 27 years...........	.160	1.78	1.46	.70	11.1	9.1	1.2
1642	Cereal crops 27 years......	.155	1.56	1.36	.74	10.1	8 8	1.1
1643	Cereal crops 27 years....	.154	1.61	1.52	.72	10.5	9.9	1.0
1644	Cereal crops 30 years...........	.172	1.79	1.50	.50	10.4	8.7	1.2
1646	Cereal crops 30 years....	.162	1.60	1.24	.46	9.9	7.7	1.3
1648	Cereal crops 30 years...........	.145	1.42	1.04	.76	9.8	7.2	1.4
1650	Cereal crops 23 years, alfalfa 7 years...........	.165	1.68	1.24	.78	10.2	7.5	1.3
1651	Cereal crops 16 years, alfalfa 6 years.	.152	1.60	1.25	.57	10.5	8.2	1.3
1653	Cereal crops 22 years, alfalfa 5 years...........	.168	1.82	1.42	.80	10.8	8.5	1.3
1656	Cereal crops 30 years.	.177	1.86	1.52	.84	10.5	8.6	1.2

TABLE 10.—*Samples of surface soil from prairies in various parts of Nebraska.*

Soil No.	Depth	County	Nitrogen	Carbon	Humus	Humus ash	Ratios		
							$\frac{C}{N}$	$\frac{Humus}{N}$	$\frac{C}{Humus}$
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
1560	1-12 in..	Pawnee.	.237	3.01	2.77	....	12.7	11.7	1.1
1561	1-12 in..	Pawnee.	.288	3.45	3.28	......	12.0	11.4	1.0
1563	1-6 in...	Pawnee.	.273	3.17	....	....	11.6	....	....
1539	1-6 in...	Thayer .	.247	3.04	....	......	12.3	....	....
1540	1-6 in...	Thayer .	.240	2.82	. ....	....	11.8	. .....	....
1557	1-6 in...	Custer..	.202	2.51	1.64	.67	12.4	8.1	1.5
1559	1-6 in...	Nance ..	.242	2.90	2.04	1.48	12.0	8.4	1.4
1415	1-6 in...	Frontier	.197	2.40	1.54	.32	12.2	7.8	1.6
1603	1-6 in...	Lincoln.	.175	2.06	1.45	.51	11.8	8.3	1.4
1958	1-6 in...	Perkins.	.169	1.89	1.28	....	11.2	7.6	1.5
1959	1-6 in...	Perkins.	.132	1.48	.95	....	11.2	7 2	1.6
1960	1 6 in...	Perkins.	.092	1.00	.74	....	10.9	8.0	1.4

The percentages of nitrogen, carbon, and humus decrease from the surface downward. They are lower in the surface six inches and in the surface twelve inches of cultivated fields than in similar depths of the adjacent prairies.

The *carbon-nitrogen ratio* decreases thru the first three feet of the upland prairies, but in the case of the lowland field it remains constant until the black soil has been passed thru, When the different inch sections of the surface foot are compared it is seen that there is, in general, an irregular decrease from the surface downward, but only in the case of the series from the upland grove is this decrease rapid. In the case of the surface six inches or twelve inches of prairies the highest ratio found was 12.7 and the lowest 10.2. Even between the soils from the extreme eastern and the extreme western parts of the state no characteristic difference was found. In samples taken to a depth of six inches the ratio was, in general, lower in the case of the cultivated fields than in the adjacent prairies. With the samples taken to a depth of twelve inches the ratio was markedly lower in the cultivated fields.

With the samples from different foot sections the *humus-nitro-*

gen ratio was found to decrease from the surface downward except in the lowland fields. Within the surface foot there was no definite decrease from the first to the twelfth inch. In the case of the surface six inches the ratio is much higher in the samples from the eastern part of the state than in those from the western. Between the surface soil of long cultivated fields and that of adjacent prairies no distinct difference was shown except where more or less of the surface had been eroded as a result of cultivation.

The *carbon-humus ratio* in the case of the Lancaster county upland prairie is practically a constant but in the case of the lowland grove and of the Antelope county prairie there is a distinct decrease thru the first few inches. For the surface foot the ratio is distinctly higher for soils from the western part of the state than for those from the eastern. It appears, in general, to be slightly lower in the surface soil of cultivated fields than in that of adjacent prairies.

The ratios for the surface soil are so nearly constant that one can satisfactorily estimate the carbon content from a nitrogen determination, thus rendering a carbon determination unnecessary for practical purposes. The actual humus determination for soils from a part of the state from which similar soils have been analyzed may well be omitted and the per cent of humus estimated from the nitrogen content.

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VARIATION IN YIELD AND METHODS OF ARRANGING PLATS TO SECURE COMPARATIVE RESULTS

BY E. G. MONTGOMERY

There is at present a demand for information regarding methods of securing comparative yield records with the smallest possible error, especially in cases where a large number of comparative tests are to be made and suitable land for this purpose is limited. There has been a rapid development in plat experiment work to answer all manner of agricultural problems; also the development of selection work for the improvement of varieties has made it necessary in some cases to make comparative yield tests of hundreds of selections, where differences of only five or ten per cent in yield were expected.

Not only is a high degree of accuracy necessary in this work, but often the area of suitable land, where all can be tested under the same conditions, is limited.

The data in this paper were secured from a plat of land 77 feet by 88 feet, which was divided by imaginary lines into 224 permanent plats, 5.5 feet square. (Fig. 1.)

The land has been sown continuously to Turkey Red winter wheat for three years. The plat was of about average uniformity and fertility, the yield averaging about 25 bushels per acre.

Each small plat has been harvested separately and the yield of grain and the per cent of nitrogen determined. The detailed data for two years, 1909 and 1910, have been submitted for publication by the United States Department of Agriculture, but the last year's data, together with summaries for three years, are given here.

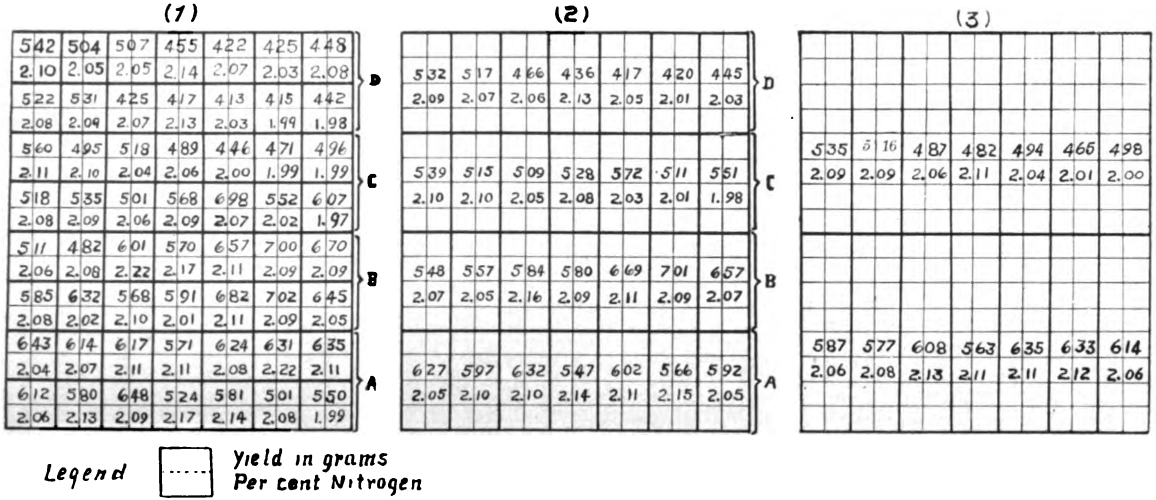
Figure 1 is a plat of the area for 1911, giving the yield of grain for each plat in grams, and the percentage of nitrogen. The average yield per block is 550.9 grams but the extreme range is 346 to 802 grams.

532 2.13	514 2.06	525 2.20	501 1.96	534 2.10	486 2.03	483 2.19	451 2.06	395 2.08	440 2.13	432 2.03	441 2.11	410 2.15	470 2.14	D
612 2.16	510 2.05	460 2.06	530 2.00	538 2.09	471 1.98	439 2.17	446 2.14	424 2.13	430 1.96	424 1.97	405 2.01	436 1.98	472 2.04	
515 2.10	480 2.20	485 2.08	534 2.06	423 2.05	421 2.11	446 2.15	393 2.02	414 2.09	421 1.97	422 1.95	423 2.03	380 1.96	432 2.02	
553 2.03	542 2.00	583 2.11	524 2.13	420 2.08	436 2.05	428 2.18	400 2.17	383 2.08	434 1.98	395 1.94	421 2.06	490 1.95	467 2.00	
575 2.12	532 2.06	550 2.09	548 2.05	480 2.04	432 2.00	420 2.04	452 2.01	460 1.97	449 1.92	474 2.11	443 2.02	484 1.94	494 2.10	C
576 2.14	559 2.13	353 2.07	530 2.21	576 2.05	583 2.07	566 2.15	517 2.04	530 2.13	346 1.98	495 1.97	474 1.88	434 1.86	573 2.05	
548 2.06	513 2.09	533 2.05	517 2.14	503 2.04	580 2.04	514 2.03	632 2.25	740 1.86	641 1.97	506 2.04	495 2.02	560 1.99	575 1.95	
550 2.01	463 2.18	550 2.08	540 2.11	497 2.00	424 2.18	519 1.95	606 2.14	756 2.44	656 2.00	584 2.10	623 1.93	599 2.00	695 1.94	
465 2.09	456 2.17	487 2.01	343 2.26	628 2.24	728 2.13	616 2.05	620 2.16	724 2.13	675 1.95	647 2.09	710 1.96	711 1.98	633 2.01	B
545 2.00	577 1.97	583 1.99	615 2.06	515 2.27	535 2.23	467 2.21	577 2.26	581 2.15	648 2.21	707 2.22	738 2.11	717 2.11	621 2.28	
504 2.02	657 2.31	760 2.14	551 1.93	528 2.07	558 2.18	575 2.11	531 2.05	686 2.10	656 1.97	716 2.19	739 2.02	730 2.08	658 2.03	
582 2.00	596 2.01	595 2.00	622 2.01	644 2.06	541 2.08	584 1.96	673 1.92	676 2.04	712 2.32	666 2.11	688 2.04	639 2.04	555 2.06	
668 2.08	662 1.98	613 2.07	693 2.10	666 2.20	643 2.03	570 2.02	674 2.16	661 2.00	742 2.12	802 2.21	634 2.22	634 2.06	634 2.07	A
661 2.07	582 2.03	590 2.03	560 2.07	585 2.14	576 2.09	500 2.08	542 2.17	557 2.05	538 2.15	500 2.29	588 2.16	685 2.16	587 2.16	
730 2.18	650 2.05	650 2.08	586 2.22	533 1.97	617 2.04	561 2.15	496 2.27	527 2.23	637 2.18	385 2.11	585 2.09	625 1.99	637 2.06	
575 1.99	495 2.04	502 2.08	584 2.16	716 2.26	725 2.10	563 2.11	477 2.14	513 2.14	649 2.03	547 2.06	488 2.06	512 1.93	426 2.00	

Legend — *Yield in grams.* / *Per cent nitrogen.*

Fig. 1.—Two hundred and twenty-four blocks 5.5 feet square, yield of grain in grams, and per cent of nitrogen in each block. Nebraska Experiment Station. 1911.

The plats may be grouped into larger and still larger plats, to note the effect on the variation in yield. Figure 2 shows the method of grouping these plats in larger plats of 4, 8, and 16 small blocks.



(1)

D	542	504	507	455	422	425	448
	2.10	2.05	2.05	2.14	2.07	2.03	2.08
	522	531	425	417	413	415	442
	2.08	2.09	2.07	2.13	2.03	1.99	1.98
C	560	495	518	489	446	471	496
	2.11	2.10	2.04	2.06	2.00	1.99	1.99
	518	535	501	568	698	552	607
	2.08	2.09	2.06	2.09	2.07	2.02	1.97
B	511	482	601	570	657	700	670
	2.06	2.08	2.22	2.17	2.11	2.09	2.09
	585	632	568	591	682	702	645
	2.08	2.02	2.10	2.01	2.11	2.09	2.05
A	643	614	617	571	624	631	635
	2.04	2.07	2.11	2.11	2.08	2.22	2.11
	612	580	648	524	581	501	550
	2.06	2.13	2.09	2.17	2.14	2.08	1.99

(2)

D	532	517	466	436	417	420	445
	2.09	2.07	2.06	2.13	2.05	2.01	2.03
C	539	515	509	528	572	511	551
	2.10	2.10	2.05	2.08	2.03	2.01	1.98
B	548	557	584	580	669	701	657
	2.07	2.05	2.16	2.09	2.11	2.09	2.07
A	627	597	632	547	602	566	592
	2.05	2.10	2.10	2.14	2.11	2.15	2.05

(3)

535	516	487	482	494	465	498
2.09	2.09	2.06	2.11	2.04	2.01	2.00
587	577	608	563	635	633	614
2.06	2.08	2.13	2.11	2.11	2.12	2.06

Fig. 2. This chart shows the plan of combining the plats into sets of 4, 8, and 16 adjacent plats.

For the purpose of comparing variation in the blocks of different sizes, it was desirable to have equal numbers of each size. The blocks were grouped in sets of 14, as indicated in figure 2 by A, B, C, D, giving four sets of the smallest size, two sets of the second size, and one set of the largest.

TABLE 1.—*Two hundred and twenty-four blocks of Turkey Red winter wheat arranged according to variation in yield, and in groups of 4, 8, and 16 adjacent plats. Nebraska Experiment Station. 1911.*

4 sets of 4 adjacent blocks in a group				2 sets of 8 adjacent blocks in a group		1 set of 16 adjacent blocks in a group	
Average yield	Deviation	Average yield	Deviation	Average yield	Deviation	Average yield	Deviation
A		C		AB			
Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
501.00	94.07	446.00	86.43	547.00	57.21	465.00	85.30
524.00	71.07	471.00	61.43	548.00	56.21	482.00	68.30
550.00	45.07	489.00	43.43	557.00	47.21	487.00	63.30
571.00	24.07	495.00	37.43	566.00	38.21	494.00	56.30
580.00	15.07	496.00	36.43	580.00	24.21	498.00	52.30
581.00	14.07	501.00	31.43	584.00	20.21	516.00	34.30
612.00	16.93	518.00	14.43	592.00	12.21	535.00	15.30
614.00	18.93	518.00	14.43	597.00	7.21	563.00	12.70
617.00	21.93	535.00	2.57	602.00	2.21	577.00	26.70
624.00	28.93	552.00	19.57	627.00	22.79	587.00	36.70
631.00	35.93	560.00	27.57	632.00	27.79	608.00	57.70
635.00	39.93	568.00	35.57	657.00	52.79	624.00	73.70
643.00	47.93	607.00	74.57	669.00	64.79	633.00	82.70
648.00	52.93	698.00	165.57	701.00	96.79	635.00	84.70
595.07	37.68	532.43	46.49	604.21	37.85	550.30	53.60
B		D		CD			
482.00	132.00	413.00	49.00	417.00	80.00		
511.00	103.00	415.00	47.00	420.00	77.00		
568.00	46.00	417.00	45.00	436.00	61.00		
570.00	44.00	422.00	40.00	445.00	52.00		
585.00	29.00	425.00	37.00	466.00	31.00		
591.00	23.00	425.00	37.00	509.00	12.00		
601.00	13.00	442.00	20.00	511.00	14.00		
632.00	18.00	448.00	14.00	515.00	18.00		
645.00	31.00	455.00	7.00	517.00	20.00		
657.00	43.00	504.00	42.00	528.00	31.00		
670.00	56.00	507.00	45.00	532.00	35.00		
682.00	68.00	522.00	60.00	539.00	42.00		
700.00	86.00	531.00	69.00	551.00	54.00		
702.00	88.00	542.00	80.00	572.00	75.00		
614.00	55.71	462.00	42.28	497.00	43.00		

TABLE 2.—*Summary of 224 blocks of winter wheat, each 5.5 feet square, to show effect on variation of combining in larger plats. Nebraska Experiment Station. 1911.*

Number of plats in group		Mean yield per block	Extreme variation	Average deviation	Standard deviation	Coefficient of variability
		Grams				***Per cent***
224 blocks 5.5 feet square..............		550.9	346.0 — 802.0	79.58	96.45	17.50
4 adjacent blocks in a group.......	A 14	595.07	501.0 — 648.0	37.68	43.82	7.35
	B 14	614.00	482.0 — 702.0	55.71	65.44	10.65
	C 14	532.43	446.0 — 698.0	46.49	61.33	11.52
	D 14	462.00	413.0 — 542.0	42.28	46.42	10.00
Average		550.87	460.5 — 647.5	45.54	54.25	9.88
8 adjacent blocks in a group.......	AB 14	604.21	547.0 — 701.0	37.85	45.48	7.52
	CD 14	497.00	417.0 — 572.0	48.59	48.74	9.80
Average		550.60	482.0 — 636.5	43.22	47.11	8.66
16 adjacent blocks in a group......	14	550.30	465.0 — 635.0	53.57	58.59	10.65

TABLE 3.—*Two hundred and twenty-four blocks of Turkey Red winter wheat, arranged according to variation in yield and in groups of 4, 8, and 16 plats not adjacent. Nebraska Experiment Station. 1911.*

Every 56th block, 4 blocks in a group				Every 28th block 8 blocks in a group		Every 14th block 16 blocks in a group	
Average yield	Deviation	Average yield	Deviation	Average yield	Deviation	Average yield	Deviation
Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
510.00	41.64	516.00	38.93	522.00	31.43	532.00	19.00
514.00	37.64	519.00	35.93	536.00	17.43	537.00	14.00
528.00	23.64	536.00	18.93	538.00	15.43	544.00	7.00
528.00	23.64	540.00	14.93	539.00	14.43	545.00	6.00
545.00	6.64	543.00	11.93	546.00	7.43	545.00	6.00
547.00	4.64	547.00	7.93	547.00	6.43	546.00	5.00
550.00	1.64	549.00	5.93	557.00	3.57	547.00	4.00
554.00	2.36	556.00	1.07	559.00	5.57	549.00	2.00
555.00	3.36	562.00	7.07	560.00	6.57	551.00	0.00
567.00	15.36	564.00	9.07	564.00	10.57	551.00	0.00
567.00	15.36	565.00	10.07	565.00	11.57	556.00	5.00
573.00	21.36	573.00	18.07	567.00	13.57	557.00	6.00
591.00	39.36	593.00	38.07	570.00	16.57	563.00	12.00
594.00	42.36	606.00	51.07	578.00	24.57	591.00	40.00
551.64	19.93	554.93	19.21	553.43	13.22	551.00	9.00
490.00	64.07	470.00	72.78	503.00	45.28		
508.00	46.07	493.00	49.78	526.00	22.28		
529.00	25.07	515.00	27.78	534.00	14.28		
535.00	19.07	516.00	26.78	537.00	11.28		
535.00	19.07	524.00	18.78	537.00	11.28		
539.00	15.07	538.00	4.78	542.00	6.28		
548.00	6.07	538.00	4.78	543.00	5.28		
549.00	5.07	544.00	1.22	547.00	1.28		
560.00	5.93	560.00	17.22	549.00	0.72		
569.00	14.93	563.00	20.22	554.00	5.72		
579.00	24.93	566.00	23.22	560.00	11.72		
601.00	46.93	570.00	27.22	561.00	12.72		

TABLE 4.—*Summary of 224 blocks of winter wheat, showing result of repeating by systematic method on reducing variability. Nebraska Experiment Station. 1911.*

Number of plats in group		Mean yield per block	Extreme variation	Average deviation	Standard deviation	Coefficient of variability
		Grams				*Per cent*
224 blocks, 5.5 feet square....		550.96	346.0 — 802.0	79.58	96.45	17.50
Every 56th block, 4 blocks in a group	14	551.64	510.0 — 594.0	19.93	24.82	4 50
	14	554.07	490.0 — 611.0	28.51	34.53	6.23
	14	554.93	516.0 — 606.0	19.21	24.27	4.37
	14	542.78	470.0 — 630.0	29.29	37.89	6.98
Average..		550.85	496.5 — 610.2	24.23	30.38	5.52
Every 28th block, 8 blocks in a group	14	553.43	522.0 — 578.0	13.22	15.18	2.74
	14	548.26	503.0 — 616 0	16.75	24.46	4.46
Average..		550.84	512.5 — 597.0	14.98	19.82	3.60
Every 14th block, 16 blocks in a group	14	551.00	532.0 — 591.0	9.00	13.43	2.44

Table 1 is an arrangement of the plats in each set of 14, ranked according to yield. This plan was used in order to bring out more clearly the range of variation and the degree of variation from the mean.

Table 2 is a summary statement showing the degree of variation for the three sized blocks. The original small blocks had a coefficient of variability amounting to 17.5 per cent, which was reduced to 9.88 per cent when the plats were made four times as large. However, further increase in size did not reduce the variation. This is not quite in accord with previous years. (See Table 5.)

The same blocks may be combined into larger units by another means, namely, systematic repetition. Thus we may take every 56th block, as, for example, blocks 1, 57, 113, and 169, and combine the yield. In this manner the blocks have been grouped into sets of 4, 8, and 16, and the detailed data are arranged in Table 3. Table 4 is a summary, and shows a marked reduction in variability as a result of systematic duplication. The comparative results secured by the two methods of combination are more clearly seen in Table 5, which is a summary for 1911 and a combined summary for three years.

TABLE 5.—*Summary. Comparison of effect of increasing size of block, versus systematic repetition, on decreasing variation in yield. 1911.*

SEASON OF 1911.

Method of combining blocks	Coefficient of variability			
	Single blocks	Sets of 4	Sets of 8	Sets of 16
	Per cent	*Per cent*	*Per cent*	*Per cent*
Blocks adjacent	17.5	9.88	8.66	10.65

In this case increasing the size of plat above four adjacent blocks has had very little effect on reducing variation. It would appear therefore that for this particular piece of land there would be no object in having plats larger than this minimum size, which is eleven feet square. It does not follow that the same area would be found to be minimum size under other conditions.

However, systematic repetition has had a very marked effect on reducing variability. While it might appear that increasing the size of the plat should reduce the error more rapidly than it does from the standpoint of increasing the number of plants and including more local soil variations, yet an equal number of large plats reaches over into new territory and includes new causes for variation. On the other hand, systematic repetition if indefinitely increased will reduce variation to zero.

VARIABILITY IN NITROGEN CONTENT

A similar study was made regarding the variability in the per cent of nitrogen. Tables 6 to 10 inclusive give the data and are self-explanatory.

TABLE 6.—*Two hundred and twenty-four blocks of Turkey Red winter wheat arranged according to variation in nitrogen and in groups of 4, 8, and 16 adjacent blocks. Nebraska Experiment Station. 1911.*

4 sets of 4 adjacent blocks in a group				2 sets of 8 adjacent blocks in a group		1 set of 16 adjacent blocks in a group	
Average per cent nitrogen	Deviation	Average per cent nitrogen	Deviation	Average per cent nitrogen	Deviation	Average per cent nitrogen	Deviation
A		C		AB			
1.990	.1100	1.970	.0780	2.050	.0460	2.000	.0760
2.040	.0600	1.990	.0580	2.050	.0460	2.010	.0660
2.060	.0400	1.990	.0580	2.050	.0460	2.040	.0360
2.070	.0300	2.000	.0480	2.070	.0260	2.060	.0160
2.080	.0200	2.020	.0280	2.070	.0260	2.060	.0160
2.080	.0200	2.040	.0080	2.090	.0060	2.060	.0160
2.090	.0100	2.060	0120	2.090	.0060	2.080	.0040
2.110	.0100	2.060	.0120	2.100	.0040	2.090	.0140
2.110	.0100	2.070	.0220	2.100	.0040	2.090	.0140
2.110	.0100	2.080	.0320	2.110	.0140	2.110	.0340
2.130	.0300	2.090	.0420	2.110	.0140	2.110	.0340
2.140	.0400	2.090	.0420	2.140	.0440	2.110	.0340
2.170	.0700	2.100	.0520	2.150	.0540	2.120	.0440
2.220	.1200	2.110	.0620	2.160	.0640	2.130	.0540
2.100	.0414	2.048	.0396	2.096	.2860	2.076	.0327
B		D		CD			
2.010	.0810	1.980	.0840	1.980	.0760		
2.020	.0710	1.990	.0740	2.010	.0460		
2.050	.0410	2.030	.0340	2.010	.0460		
2.060	.0310	2.030	.0340	2.030	.0260		
2.080	.0110	2.050	.0140	2.030	.0260		
2.080	.0110	2.050	.0140	2.050	.0060		
2.090	.0010	2 070	.0060	2.050	.0060		
2.090	.0010	2.070	.0060	2.060	.0040		
2.090	.0010	2.080	.0160	2.070	.0140		
2.100	.0090	2.080	.0160	2.080	.0240		
2.110	.0190	2.090	.0260	2.090	.0340		
2.110	.0190	2.100	.0360	2.100	.0440		
2.170	.0790	2.130	.0660	2.100	.0440		
2.220	.1290	2.140	.0760	2.130	.0740		
2.091	.0360	2.064	.0359	2.056	.0336		

TABLE 7.—*Summary of 224 blocks of winter wheat, each 5.5 feet square, to show effect of combining in larger plats on variability in nitrogen content. Nebraska Experiment Station. 1911.*

Number of plats in group		Mean per cent nitrogen	Extreme variations	Average deviation	Standard deviation	Coefficient of variability
						Per cent
224 single blocks......		2.077	1.86 — 2.44	.0724	.0915	4.40
4 adjacent blocks in a group	A 14	2.100	1.99 — 2.22	.0414	.0542	2.58
	B 14	2.091	2.01 — 2.22	.0360	.0622	2.49
	C 14	2.048	1.97 — 2.11	.0396	.0446	2.18
	D 14	2.064	1.98 — 2.14	.0359	.0447	2.17
Average		2.076	1.99 — 2.17	.0382	.04892	2.35
8 adjacent blocks in a group......	AB 14	2.096	2.05 — 2.16	.0286	.0350	1.67
	CD 14	2.056	1.98 — 2.14	.0336	.0403	1.96
Average		2.076	2.01 — 2.14	.0311	.0376	1.81
16 adjacent blocks in a group......	14	2.076	2.00 — 2.13	.0327	.0387	1.86

TABLE 8.—*Two hundred and twenty-four blocks Turkey Red winter wheat arranged according to variation in nitrogen content, and in groups of 4, 8, and 16 plats not adjacent. Nebraska Experiment Station.*

Every 56th block, 4 in a group				Every 28th block, 8 in a group		Every 14th block, 16 in a group	
Per cent nitrogen	Deviation	Per cent nitrogen	Deviation	Per cent nitrogen	Deviation	Per cent nitrogen	Deviation
2.000	.0670	2.000	.0890	2.020	.0600	2.040	.0370
2.010	.0570	2.010	.0790	2.020	.0600	2.040	.0370
2.020	.0470	2.010	.0790	2.050	.0300	2.060	.0170
2.040	.0270	2.020	.0690	2.060	.0200	2.060	.0170
2.060	.0070	2.040	.0490	2.060	.0200	2.070	.0070
2.060	.0070	2.080	.0090	2.070	.0100	2.070	.0070
2.070	.0030	2.090	.0010	2.080	.0000	2.080	.0030
2.080	.0130	2.110	.0210	2.080	.0000	2.080	.0030
2.080	.0130	2.120	.0310	2.090	.0100	2.090	.0130
2.090	.0230	2.120	.0310	2.100	.0200	2.090	.0130
2.100	.0330	2.130	.0410	2.110	.0300	2.090	.0130
2.100	.0330	2.140	.0510	2.120	.0400	2.100	.0230
2.110	.0430	2.140	.0510	2.130	.0500	2.100	.0230
2.120	.0530	2.230	.1410	2.130	.0500	2.110	.0330
2.067	.0304	2.089	.0530	2.080	.0286	2.077	.0176
1.980	.0760	2.010	.0810	2.020	.0530		
2.000	.0560	2.040	.0510	2.020	.0530		
2.010	.0460	2.040	.0510	2.060	.0130		
2.020	.0360	2.060	.0310	2.070	.0030		
2.030	.0260	2.070	.0210	2.070	0030		
2.050	.0060	2.080	.0110	2.070	.0030		
2.070	.0140	2.090	.0010	2.070	.0030		
2.070	.0140	2.090	.0010	2.070	.0030		
2.080	.0240	2.110	.0190	2.070	.0030		
2.080	.0240	2.110	.0190	2.080	.0070		
2.090	.0340	2.130	.0390	2.080	.0070		
2.090	.0340	2.130	.0390	2.110	.0370		
2.100	.0440	2.160	.0690	2.110	.0370		
2.110	.0540	2.160	.0690	2.120	.0470		
2.056	.0349	2.091	.0359	2.073	.0194		

TABLE 9.—*Summary of 224 blocks of winter wheat, showing effect of repeating by a systematic method on reducing variability. Nebraska Experiment Station. 1911.*

Number of plats in group		Mean per cent nitrogen	Extreme variation	Average deviation	Standard deviation	Coefficient of variability
						Per cent
224 blocks, 5.5 feet square		2.077	1.86 — 2.440	.0724	.0915	4.400
Every 56th block, 4 blocks in a group	14	2.067	2.00 — 2.120	.0304	.0363	1.750
	14	2.056	1.98 — 2.110	.0349	.0394	1.910
	14	2.089	2.00 — 2.230	.0530	.0637	3.050
	14	2.091	2.01 — 2.160	.0359	.0433	2.070
Average		2.076	2.00 — 2.150	.0385	.0457	2.195
Every 28th block, 8 blocks in a group	14	2.080	2.02 — 2.130	.0286	.0348	1.670
	14	2.073	2.02 — 2.120	.0194	.0279	1.350
Average		2.076	2.02 — 2.125	.0240	.0313	1.510
Every 14 blocks, 16 blocks in a group	14	2.077	2.04 — 2.110	.0176	.0208	1.000

It is interesting to note that the coefficient of variability is not as great with the per cent of nitrogen as with the yield, being 4.79 per cent for the three-year average against 14.66 per cent.

Practically the same results were secured here as in the former case. Combining four adjacent blocks reduced variability to about one-half, but further increase in size had only small effect. However, systematic repetition gave constant decrease.

Table 10 is a summary for 1911 and also combined summary for 3 years, 1909-'10-'11.

TABLE 10.—*Summary. Comparison of increasing size of block. versus systematic repetition, on decreasing variation in per cent nitrogen. 1911.*

SEASON OF 1911.

Method of combining blocks	Coefficient of variability			
	Single blocks	Sets of 4	Sets of 8	Sets of 16
	Per cent	*Per cent*	*Per cent*	*Per cent*
Blocks adjacent........	4.40	2.35	1.81	1.86
Systematic repetition...	4.40	2.19	1.51	1.00

COMPARISON FOR THREE YEARS—1909, 1910, 1911.

Blocks adjacent........	4.79	2.42	2.08	2.09
Systematic selection....	4.79	2.28	1.49	1.09

VARIATION ON THE SAME PLATS FROM YEAR TO YEAR

It was noticeable from the first that certain areas of the large plat averaged distinctly higher than the average, while other areas were low. Figure 3 is a chart showing the location of the high and low areas for three successive years. The high area shifted in the three years from the northwest quarter to the east side. In fact, a portion of the very area which was high in 1909 was low in 1910. The cause of this shift is not clear. There were seasonal changes, and certain of these areas may have been better suited than others to the requirements of different seasons. Also, as the land was continually in wheat for three years it is possible that one portion was better able to produce under continuous wheat cropping. Whatever the cause or causes of this shift in high and low yield, it illustrates the difficulty in standardizing the yield of plats.

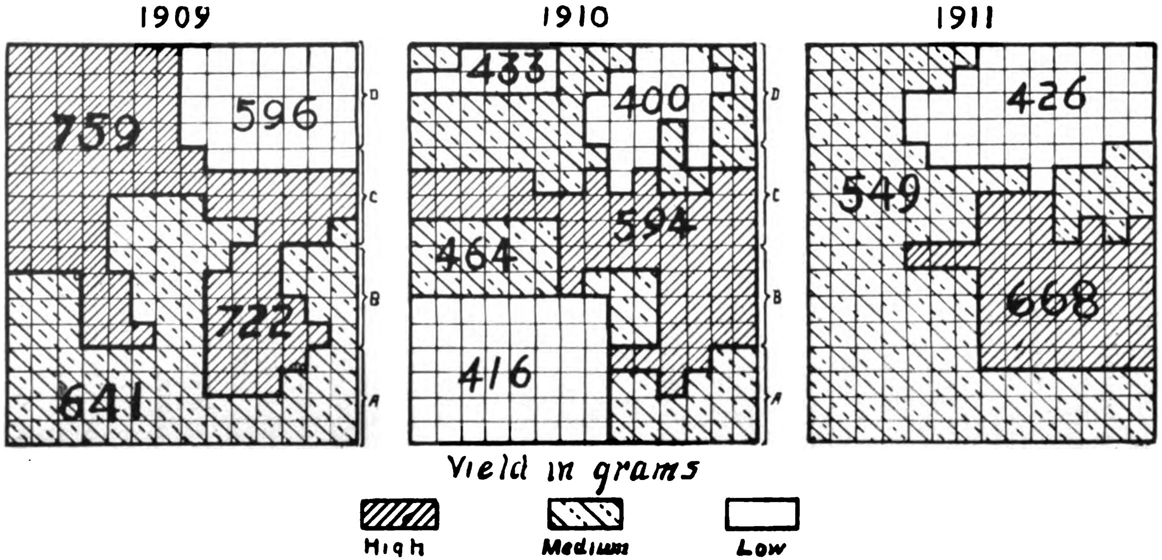


Fig. 3. Chart showing the "high" areas and "low" areas in yield of grain for three years, 1909-1911. The high area tended to shift toward the southeast part of the plat. The figures indicate average yield in grams per plat.

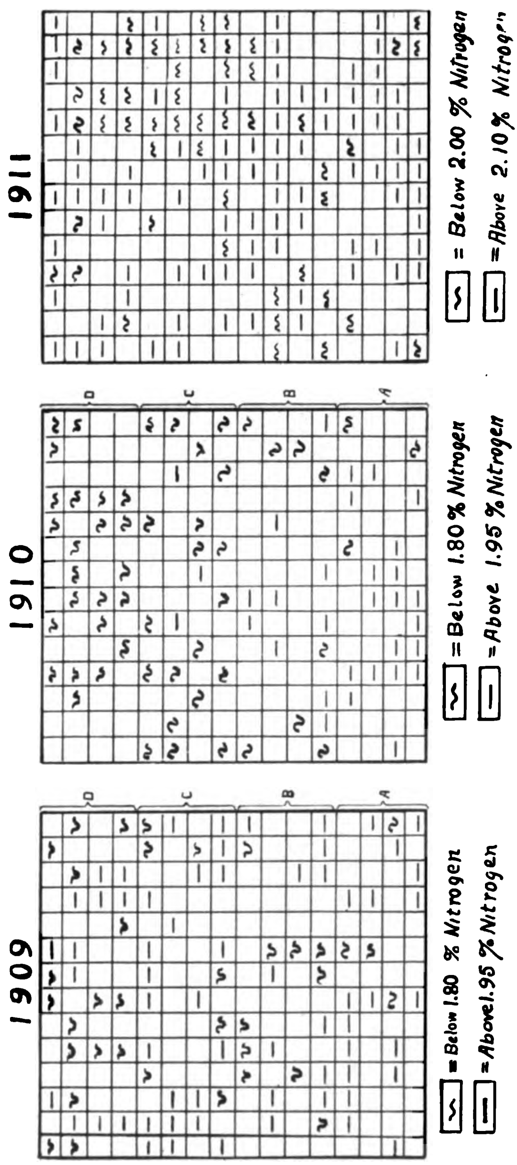

1909
1910
1911
A
B
C
D
~ = Below 1.80 % Nitrogen
| = Above 1.95 % Nitrogen
~ = Below 1.80 % Nitrogen
| = Above 1.95 % Nitrogen
~ = Below 2.00 % Nitrogen
| = Above 2.10 % Nitrogen

Fig. 4. Showing location of plats high or low in average nitrogen content. The variation in nitrogen in the plats is not great (see Tables 7, 8, and 9). There is some tendency for the plats producing high nitrogen wheat and low nitrogen wheat to localize, but this tendency apparently bears no relation to variation in yield.

Increasing the size of the plat has only a slight effect on decreasing the variability after a certain minimum size is reached.

The only method of securing comparative yield tests that will meet all of the fluctuating variations is systematic repetition.

With sufficient repetition very small plats may be used and thus a large number of comparative tests made on a rather small area of ground.

We have found a block 5.5 by 16 feet to be a very convenient size. This makes three plats to the square rod or 480 plats per acre. Forty-eight comparative tests per acre can be made, repeating each 10 times, with a much higher degree of accuracy than when tenth-acre plats are repeated twice or three times.

PRELIMINARY REPORT ON EFFECT OF CLOSE AND BROAD BREEDING ON PRODUCTIVENESS IN MAIZE

By E. G. Montgomery

It has been known for many years that self-fertilization has an injurious effect on the yield of corn, and on the other hand it has been observed that broad breeding or the cross of two unrelated strains has often been quite beneficial. It is possible to conceive of several degrees of relationship between self-fertilization on one hand and the crossing of two unrelated varieties on the other. The object of this experiment was to determine, if possible, the degree of relationship where close fertilization ceased to be injurious and where crossing became beneficial. The problem came up in connection with the question of handling certain high-yielding strains, which had been secured in the ear-to row breeding work. The question was, whether it would be advisable to use a single high-yielding ear as a foundation stock or to cross together a number of desirable ears in order to maintain yield. If a single desirable ear could be safely used as a foundation stock and the yield indefinitely maintained, it would simplify our work in the improvement of corn.

In 1907 a series of ear-to-row breeding plats were put out at the Experiment Station. The progeny of four of the best-yielding rows was used as a basis for the degree-of-relationship experiments here described. Five ears were selected from the progeny of these four original ears, and a part of each ear was planted in an isolation plat. In a second plat a part of each ear was planted for close-breeding experiments and in the third plat a cross-fertilization experiment was started, using ears from other high-yielding strains of the same variety. It was proposed to test the following degrees of relationship:

No. 1. *Self-Fertilization.*—In this case the ear would each time be fertilized by pollen from the tassel in the same plant.

No. 2. *Close-Fertilization.*—Each ear would be fertilized by a mixture of pollen from 10 to 15 sister plants. Continued each year from a single ear.

No. 3. *Close-Fertilization.*—Each ear would be fertilized by a composite sample of pollen from fifteen sister plants, all from the same original ear. Stock continued from composite sample of 15 ears.

No. 4. *Cross-Fertilization.*—In this case each year a part of the plants from each strain will be detasseled to be fertilized by plants from one of the other three strains.

No. 5. *Ear-to-Row Breeding.*—Nos. 3 and 4 above had been taken from the best four strains of our old Class 1, which has been bred by the ear-to-row method since 1903. (See Nebr. Bul. No. 112, p. 5.)

No. 6. *Check Plats.*—This seed is secured each year from the original grower of the corn, Mr. R. Hogue of Crete, Nebr. He practices the customary method of selecting good ears from the field. It is not known whether the yielding power of the check is also changing.

The work has been continued for three years, 1909, 1910, and 1911. This report is necessarily preliminary and it is proposed here to give a report only on observations made so far.

The following yields were secured in 1911:

TABLE 1.—*Showing effect on yield, of five different methods of fertilizing corn for seed, based on relationship.*

Method	Description of method	Yield per acre in 1911
		Bushels
No. 1	Inbred for two years (1909-1910)	9.90
No. 2	Close bred for two years. Stock continued each year from a single ear	37.66
No. 3	Close bred for two years. Stock continued each year from a composite of 15 ears	41.30
No. 4	Natural cross breeding (4 strains intercrossed each year by detasseling)	43.89
No. 5	Ear-to-row selections	44.02
No. 6	Check. (Original corn grown under field conditions and best ears selected for seed)	40.70

COMMENTS ON RESULTS

INBREEDING.—(No. 1.) Figure 1 is a photograph illustrating the relative sizes of Nos. 1, 2, and 4. It is apparent here that the inbred corn has been much reduced in size and yield. Two inbred strains were practically sterile in 1910 and two more in 1911. Not all the inbred strains have been equally reduced, some being fairly productive, as indicated by the following estimate of yield for the strains in 1911:

TABLE 2.—*Yield of inbred strains of corn, 1911.*

Plat No.	Yield	Plat No.	Yield
	Bushels		*Bushels*
1	22.2	7	10.8
2	3.0	8	1.6
3	Sterile	9	8.5
4	4.2	10	18.1
5	23.2	11	7.3
6	Sterile	12	15.1

This reduction in yield and vigor has been noted by Shull[1] and East.[2] East also found that certain strains withstood inbreeding with less reduction and yield than others. It is possible that strains may be found that withstand inbreeding indefinitely without becoming sterile.

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[1] Shull, Geo. H. Vol. IV, p. 296 (1907); Vol. VI, pp. 63-72 (1909).

[2] East, E. M. Inheritance in Maize. Conn. Exp. Sta. Bul. 167 (1911).

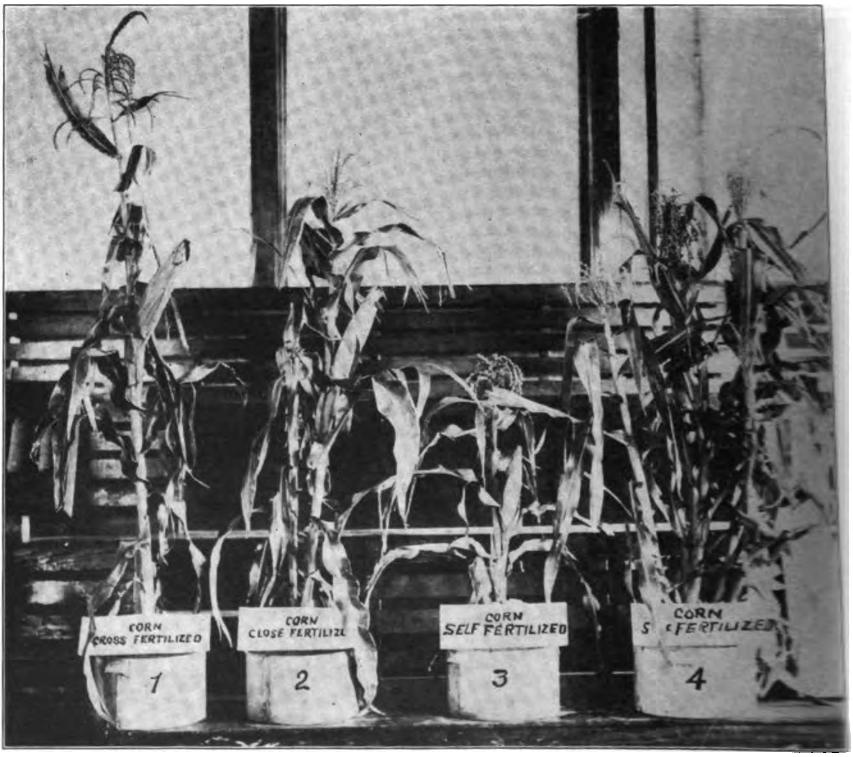


Fig. 1. The effect of three degrees of relationship in crossing is here illustrated. Nos. 3 and 4 are pure strains from seed-stock inbred for

from tillers, while others showed great capacity for tillering, developing two or three tillers as large as the primary plant. In one type all the stalks had a decided red color, and in another case the plants were very large, with a bend approximating one-fourth their height near the base. Figures 4, 5, 6, and 7 illustrate some of the types secured.

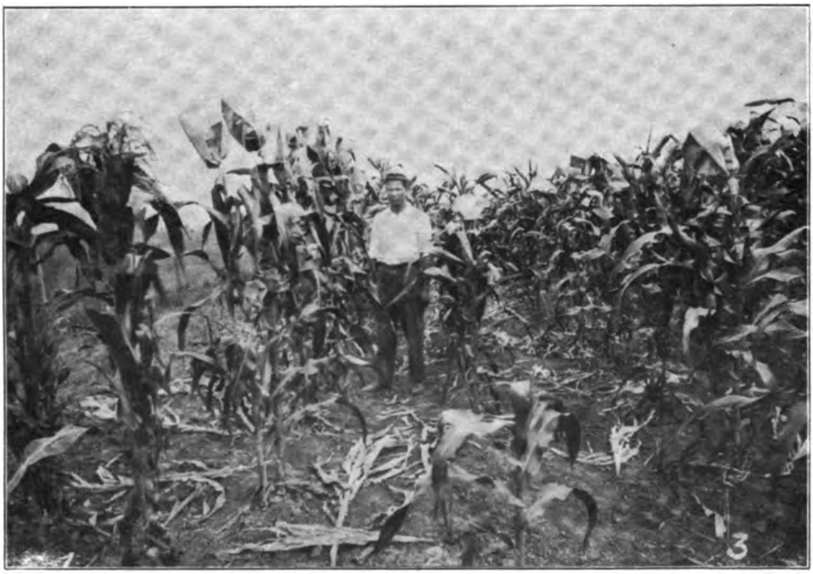


Fig. 2. The effect of inbreeding is here illustrated. Row 2 is from seed ear inbred for two years and is about one-half normal size. Row 1 is also from seed ear inbred two years but has not yet shown injurious effect. Row 3 is from a cross-bred seed ear.

CLOSE BREEDING.—(No. 2.) In this case pollen from sister plants has been used to fertilize each ear; but stock continued each year from a single ear. Eleven close bred strains were grown this year, and gave variable results, the yield ranging from 27.13 bushels to 58.18 bushels per acre, the average being 37.66 bushels. The plants were reduced in vigor. (See figure 1.) In time probably they would be as much reduced as the inbred plants, as the chances are that the strains would be slowly brought to homozygous types.

The yield is already considerably reduced and will be further reduced in the future.

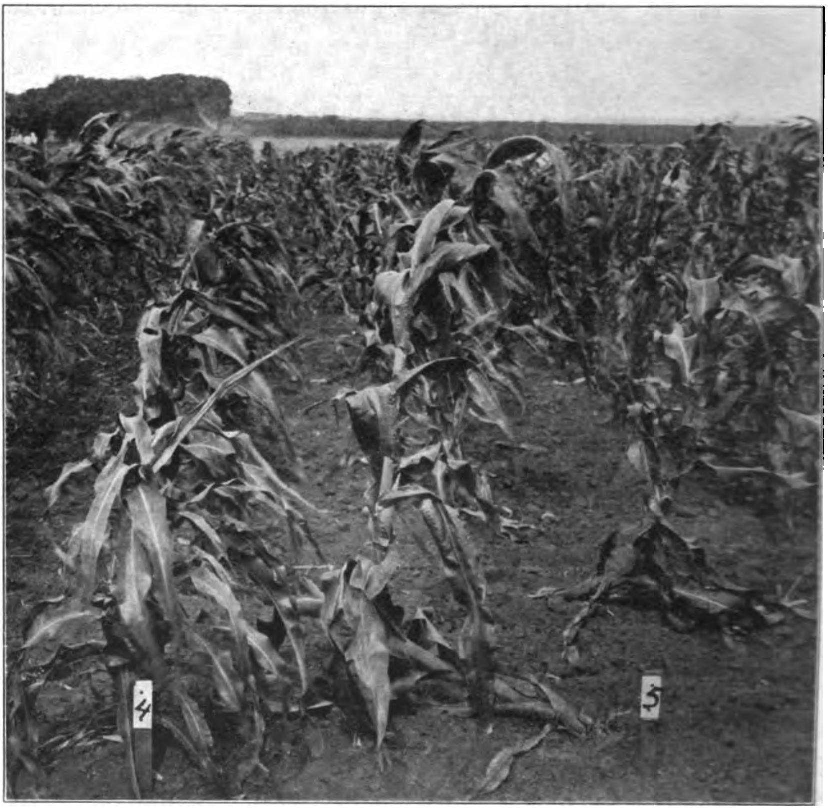


Fig. 3. Contrast in two pure types under field conditions. In row 4 all plants were sterile. In row 5 all plants were tall, coarse, with a long bend at the base.

Close Breeding.—(No. 3.) In this case a composite sample of pollen from 15 sister plants has been used to fertilize each ear, but stock continued each year from a composite of 15 ears. This was intended to illustrate a case where a single ear would be isolated and used as foundation stock for building up a strain. It is possible, however, that results are not strictly typical, as the number of seed ears from which to select seed is necessarily limited. The principal difference, however, is that if there is a decrease in yield, under the conditions of the experiment, it would be shown in fewer years than under field conditions.

Results, however, show a different reaction in the three strains under test, the yields being 52.73, 34, and 38.38 bushels per acre respectively, the average being 41.7 bushels. Results indicate a small average decrease in yield to date, and also that, while certain ears might retain a high yield when planted and continued in an isolated plat, in other cases a decided decrease is to be expected.

CROSS-BRED STRAINS.—(No. 4.) The four strains of corn used for this are the same as in Nos. 3 and 5, and originated as described under the next head. The plan has been to plant each year two rows of each thru the center of a 12-row plat of one of the other strains, detasseling the two rows, and saving seed from these two detasseled rows. The experiment has been continued with the seed harvested in this way each year. After three years the intercrossing has been so general that the original strains have lost their identity, and from now on the experiment is practically a test of using seed from detasseled rows. Yields this year give only a slightly better yield than the original check.

EAR-TO-ROW SELECTIONS.—(No. 5.) These strains originated as the result of ear-to-row selections beginning in 1903 and continuing for four years (Bul. 112, p. 5). In 1907 the best strains were grown in increase plats, but in 1908 six ears were taken from each of four strains, and the ear-to-row selection has been continued since with these. Each year six ears are selected from the best of the six rows, from each strain. The number of rows is so few that the experiment should be rather a severe test of the question, "Can yield be maintained by continued ear-to-row breeding, or will there be injurious results from close breeding?"

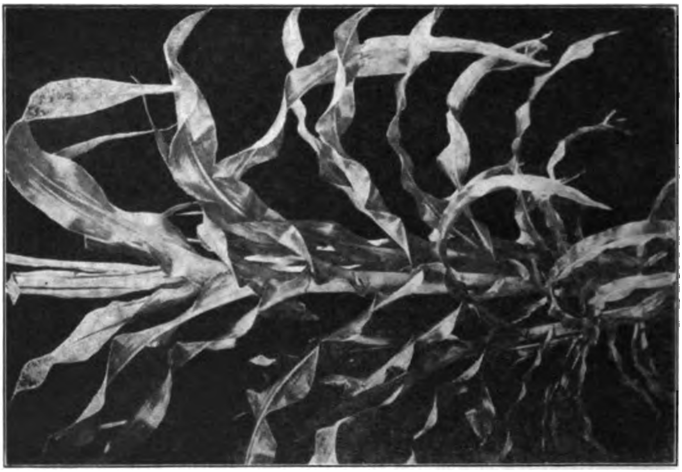
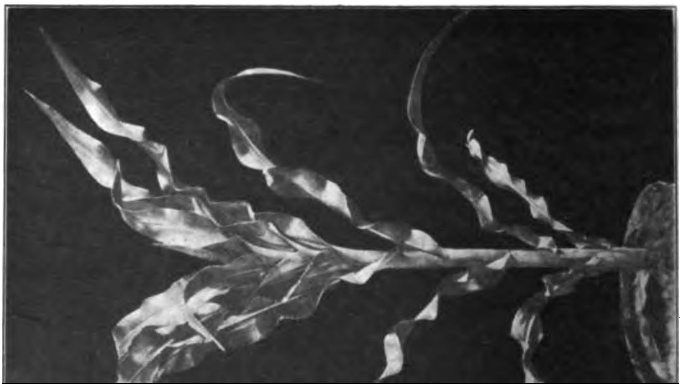
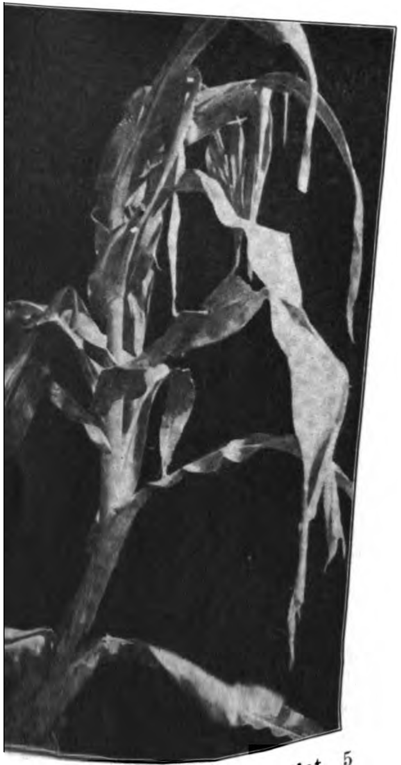


Fig. 5. Homozygous type from Plat 7 (1911). Two to three strong tillers were produced from each plant.



Homozygous type from Plat 10 1). The plants were very straight, free from tillers.



omozygous type from Plat 5
Each plant very coarse and
decided bend near the base.

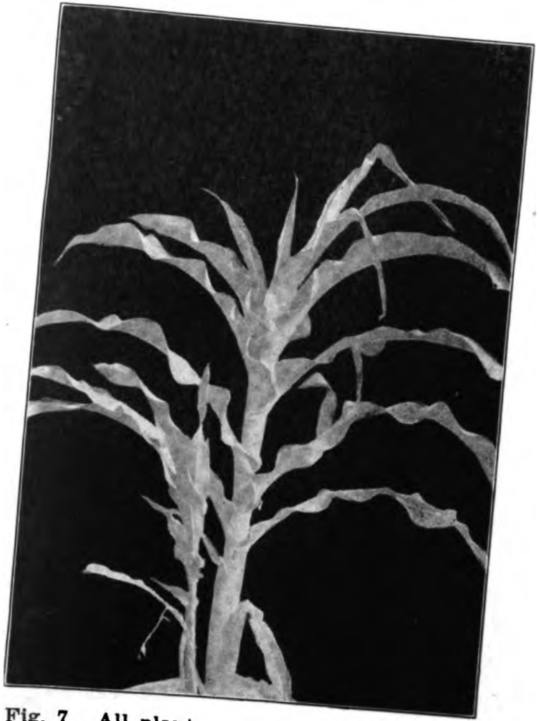


Fig. 7. All plants came true to type. The plants were practically all sterile.

Last year and this, this seed was compared with check plats, with the following results:

TABLE 3.—*Ear-row-bred seed after seven and eight years continuous selection in comparison with "check" of original corn.*

Year	Ear-row stock yield per acre	Check stock yield per acre
	Bushels	*Bushels*
1910....................	56.6	54.4
1911....................	44.0	40.7

In this case, even with very narrow ear-row selection, the stock has so far maintained its yield. With a greater number of ears better results would be expected.

IMPROVED CORN UNDER FIELD CONDITIONS.—The question has frequently arisen as to whether a stock that had been improved by ear-to-row selection would maintain its yield under field conditions. The above stock, which was placed in increase plats in 1907, has been grown under field conditions since, and compared each year with a check. The custom has been to select only good ears for seed in the ordinary way.

TABLE 4.—*Comparison of ear-to-row bred seed and "check" grown under field conditions without further selection.*

Year	Seed originated by ear-to-row breeding (Class I)	Check	Difference
	Bushels	*Bushels*	*Bushels*
1907..............	82	72.5	9.5
1908..............	66	59.0	7.0
1909..............	..	....	..
1910	58	49.1	8.9
1911..............	54	51.0	3.0

A difference in yield is still maintained, tho not as marked this last year as heretofore.

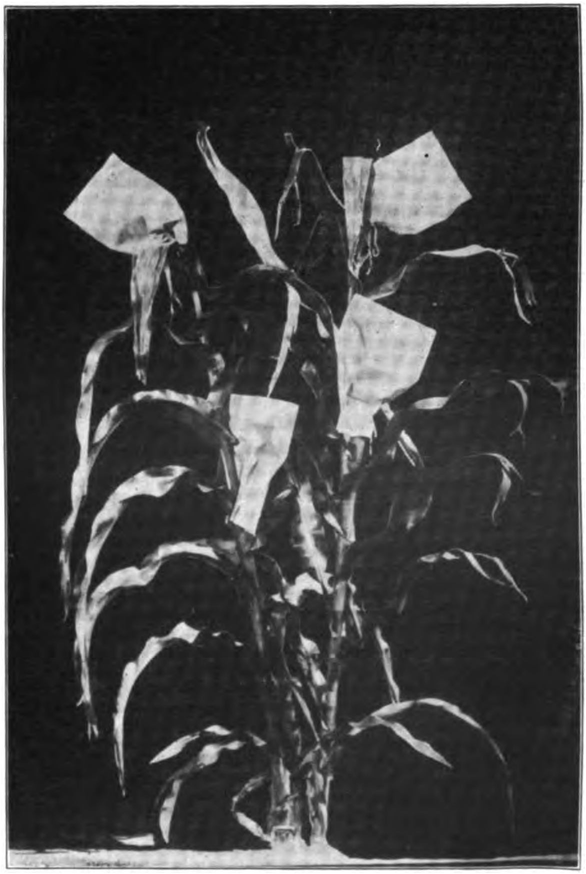


Fig. 8. Method of covering ear and tassel for inbreeding.

CONCLUSIONS

Perhaps the most important result indicated so far by the investigation is that all degrees of close relationship are injurious and the yield is improved as relationship is widened. Apparently best results would not be secured from using a single ear as foundation stock, on the average, tho certain ears might give excellent results planted in this way.

Under natural conditions, however, there is no doubt a certain amount of self and close fertilization. This must be especially true in strains where the silk and pollen are produced at the same time. Every self or close fertilized grain is apt to produce a plant much reduced in yield or barren. This probably accounts for a certain per cent of the small or barren plants in cornfields. By sowing seed from detasseled rows, all the self-fertilizing and much of the close-fertilizing is prevented, and will result in increased yield.

It may also be added that the above results will probably vary considerably with different varieties, and should be verified under a variety of conditions.

EVAPORATION FROM A FREE WATER SURFACE AT LINCOLN, NEBRASKA*

BY G. A. LOVELAND AND S. W. PERIN

The unusually dry season of 1894 directed attention to the need of a knowledge of evaporation in Nebraska and to the fact that no data were available for use. In the spring of 1895 equipment for measuring evaporation was installed on the farm of the Experiment Station near Lincoln, Nebr. A record of evaporation has been kept for the summer months to the end of the season of 1910. A summary of the records by months for the sixteen years is given in the table below. The rainfall and temperature recorded in the immediate vicinity of the pan and the wind velocity recorded on the University campus 2¼ miles distant, with the anemometer at an elevation of 82 feet, are included in the table, as they are factors affecting the evaporation so much as to be of interest in connection with amounts of evaporation.

The evaporating pan was constructed according to specifications of the United States Geological Survey. It is made of galvanized iron, 3 feet square and 10 inches deep. Around the top of the pan, on the outside, is riveted a strip of band iron. Four additional strips of band iron, riveted to the top piece, are then bent around under the pan, two strips in each direction, thus furnishing the necessary stiffness. The pan is floated by two galvanized iron pontoons, 4 feet long and 9 inches in diameter and strengthened in the middle by braces. On opposite sides of the pan the band around the top projects a distance of 6 inches to form pairs of arms by means of which the pan rests on the pontoons. The device used for determining the amount of evaporation consists of a series of inclined brass scales attached to a vertical frame, and the whole screwed to a light wooden cross-bar which rests upon the sides of the pan. These scales, which are intended only for differential measurements, are graduated downward from the top for every .05 of an inch of vertical height. Thus, a lower height of water has a higher reading on the scale.

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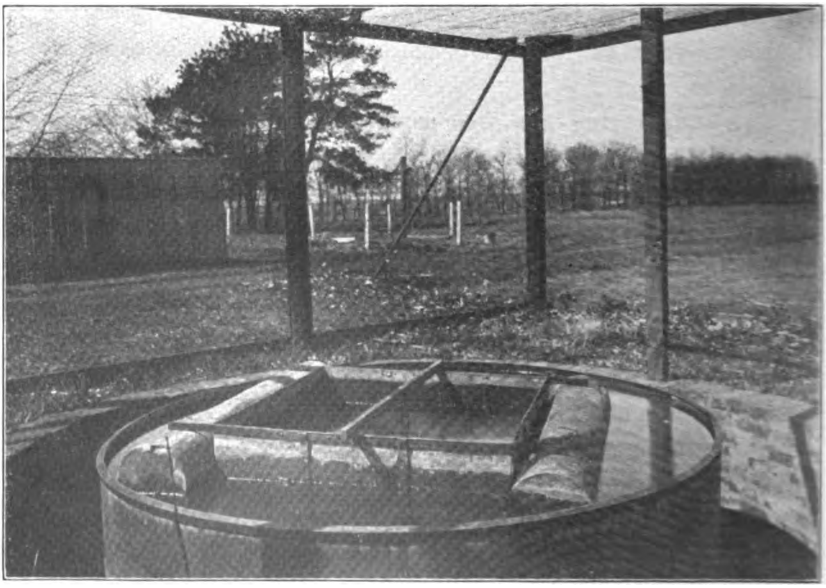
* These records were kept by Mr. Perin and were reported monthly to Mr. Loveland, the Section Director.

As no body of water well located for the exposure of the pan was accessible, a reservoir, 10 feet square by 2½ feet deep, was made, kept full of water, and the pan floated on its surface. Measurements were made once a day, in the evening about sunset. The pan was filled with water several times a month but not daily. The amount of water the pan collected during a rain was determined by a careful measurement in a rain-gage, and allowance made for this water in determining the amount of evaporation. The location and appearance of the pan are shown in the accompanying illustration.



The evaporating pan in position.

The following tables represent the monthly evaporation from a free water surface reckoned in inches. They also embody the precipitation by months as well as the mean monthly temperature and wind velocity:

	MARCH				APRIL			
Year	Evap.	Precip.	Temp.	Wind Vel.	Evap.	Precip.	Temp.	Wind Vel.
1895	....	......	......	....	......	....	.....	....
1896	.....	......	.....	....	5.03	3.99	57.8	15.2
1897	.....	......	.....	....	3.57	5.08	51.1	14.7
1898	.....	......	.....	....	5.43	2.83	50.7	13.6
1899	....	......	.....	....	......	1.51	51.4	12.8
1900	.....	......	.....	....	*2.42	4.70	54.8	12.1
1901	.....	......	.....	....	4.44	1.63	51.8	12.6
1902	.....	......	.....	....	4.79	0.76	52.1	12.7
1903	4.29	0.57	40.0	11.5	4.20	3.41	53.2	15.2
1904	.....	......	.....	....	4.67	5.13	46.0	15.6
1905	.....	......	.....	....	5.32	3.55	50.2	11.4
1906	.....	......	.....	....	4.81	2.86	56.0	13.1
1907	.....	......	.....	....	4.26	0.77	44.0	13.2
1908	.....	......	.....	....	5.89	1.93	53.7	13.6
1909	.....	......	.....	....	4.68	1.34	48.0	14.3
1910	.....	.	.....	....	6.72	0.05	56.2	15.4
Mean	......	....	....	....	†4.71	2.63	51.8	13.7
Av. daily	.....	......	.....	....	0.16	0.09	......	....

	MAY				JUNE			
Year	Evap.	Precip.	Temp.	Wind Vel.	Evap.	Precip.	Temp.	Wind Vel.
1895	6.54	1.05	61.4	8.2	5.04	5.08	70.6	9.6
1896	5.28	9.76	63.5	13.0	7.06	2.88	69.6	9.2
1897	5.80	1.94	61.3	10.2	5.61	2.01	73.0	10.8
1898	4.09	5.29	60.4	10.9	6.79	4.91	73.5	9.8
1899	5.33	2.32	63.4	12.2	5.94	8.24	72.0	11.0
1900	5.81	3.38	64.9	9.5	6.59	3.55	72.1	9.7
1901	5.50	2.10	62.0	10.6	7.09	1.59	75.9	12.1
1902	5.19	3.50	66.5	11.9	6.01	8.60	68.0	10.4
1903	6.79	11.13	61.6	12.9	5.54	2.49	66.0	8.2
1904	5.60	4.32	62.0	10.4	5.24	3.69	68.6	8.7
1905	7.00	4.72	60.7	13.0	7.79	3.59	72.7	11.3
1906	6.55	1.71	63.2	12.8	7.74	3.46	70.0	10.7
1907	6.53	3.66	57.2	13.0	6.38	6.59	69.4	10.3
1908	6.11	5.26	59.7	11.8	7.89	11.73	69.0	12.0
1909	5.91	4.60	60.6	11.5	6.68	1.95	70.7	8.6
1910	5.58	3.30	57.0	10.8	7.77	1.64	71.6	9.6
Mean	5.85	4.25	61.8	11.4	6.57	4.50	70.8	10.1
Av. daily	0.19	0.14	....	......	0.22	0.15	....	..

* For 10 days. † April, 1900, not included.

	JULY				AUGUST			
Year	Evap.	Precip.	Temp.	Wind Vel.	Evap.	Precip.	Temp.	Wind Vel.
1895	6.76	0.91	74.8	8.5	6.07	3.86	75.0	9.6
1896	7.14	4.29	74.4	8.4	5.89	3.18	69.0	9.3
1897	8.32	3.44	78.2	10.6	6.35	1.85	74.8	8.6
1898	......	6.60	74.7	9.6	7.40	2.82	75.2	9.0
1899	6.75	1.94	74.4	7.5	7.29	2.34	77.4	10.0
1900	9.09	6.68	76.2	11.6	7.07	7.96	78.7	11.7
1901	13.33	2.91	85.4	10.0	6.61	0.91	76.8	7.8
1902	7.65	11.52	75.0	10.0	4.40	4.30	73.2	8.6
1903	7.83	2.48	76.0	9.8	6.02	5.98	71.3	8.4
1904	6.23	5.03	73.0	8.9	6.08	2.48	72.6	8.2
1905	7.22	2.82	72.6	8.6	7.06	6.24	76.9	7.6
1906	5.89	7.88	71.9	7.4	5.77	2.32	74.9	8.6
1907	6.94	3.26	76.4	8.7	6.21	4.40	74.4	8.9
1908	7.02	9.58	73.8	8.4	5.58	2.30	73.2	8.4
1909	6.01	3.82	75.8	7.9	8.74	1.09	79.5	9.2
1910	7.39	2.42	76.6	8.0	5.63	14.41	73.6	8.6
Mean	7.57	4.72	75.6	9.0	6.39	4.15	74.8	8.9
Av. daily	0.24	0.15	......	....	0.21	0.14	....	....

	SEPTEMBER				OCTOBER			
Year	Evap.	Precip.	Temp.	Wind Vel.	Evap.	Precip.	Temp.	Wind Vel.
1895	5.23	0.63	74.2	13.9	......	....	......	....
1896	4.09	4.90	61.9	8.7	3.15	3.06	49.8	9.7
1897	5.97	1.92	74.6	9.9	3.14	2.62	59.9	11.2
1898	5.07	2.81	68.2	9.7	3.11	1.37	51.8	14.4
1899	6.02	0.62	66.9	10.6	3.92	2.51	59.8	11.4
1900	4.20	2.61	67.8	10.8	2.99	2.66	61.7	11.1
1901	4.95	6.36	66.4	10.7	2.92	3.20	57.0	10.0
1902	4.04	3.94	62.0	11.9	1.94	2.84	57.0	9.9
1903	4.83	1.39	63.6	12.1	4.27	2.96	55.5	10.6
1904	5.01	2.97	67.0	9.2	2.93	1.53	57.0	10.7
1905	4.19	7.69	68.3	9.5	3.48	2.69	51.8	10.3
1906	4.98	6.79	68.0	8.9	3.33	1.95	52.4	10.8
1907	5.23	3.40	66.2	9.8	3.51	1.15	53.7	9.7
1908	5.44	0.44	70.2	9.5	3.82	2.54	52.4	13.0
1909	4.68	4.48	66.6	8.0	3.76	0.47	53.2	11.1
1910	3.50	4.42	66.4	9.3	3.76	0.91	58.3	11.1
Mean	4.84	3.46	67.4	10.2	3.34	2.16	55.4	11.0
Av. daily	0.16	0.12	......	....	0.11	0.07	......	....

NOVEMBER

Year	Evap.	Precip.	Temp.	Wind Vel.
1895........	*1.27	0.51	38.6	12.6
1896........	......	....	......	....
1897........	......	....	......	....
1898........	....	....	.....	... .
1899.... ...	1.52	0.61	46.8	9.0
1900........	†0.65	0.07	37.8	9.6
1901........	‡0.35	0.42	40.6	10.1
1902.......	......	....	......	....
1903........	†1.28	1.80	38.9	11.5
1904........	§0.55	0.18	44.5	8.3
1905........	1.84	2.77	42.5	11.6
1906........	‖0.67	0.32	38.6	9.9
1907........	§0.93	1.08	39.8	10.0
1908	‖0.65	0.50	41.6	9.7

* For 19 days.
† For 14 days.
‡ For 7 days.
§ For 8 days.
‖ For 10 days.

EXPERIMENTS WITH TUBERCULIN

By J. H. Gain

The experience of some breeders who have bought cattle accompanied by a certificate of tuberculin test. especially cattle coming from without the state or the United States, has led them to believe that there are some methods used to nullify the tuberculin test. The most common belief is that the animal has been injected with tuberculin just prior to the official test. It has also been stated that by doubling the dose of tuberculin the influence of the previous dose can be overcome. The experiment here reported was undertaken to determine to what extent the tuberculin test might thus be nullified; also how long the influence of a normal dose of tuberculin would last and whether this influence could be overcome by increasing the dose.

In this experiment Government tuberculin was used.

Owing to the extreme drouth of the early summer this work was not continued as long as first intended.

At the conclusion of the experiment these cattle were shipped to South Omaha, where they were slaughtered under Government inspection and all found tuberculous. Of the ten head. seven were passed for food and three condemned as unfit for food and sent to the tank to be made into tankage and fertilizer; thus 70 per cent passed for food and 30 per cent were condemned. It might be stated here that these percentages as to disposition of carcasses are about the average for cattle that are found tuberculous upon post-mortem examination. Where herds have been given the tuberculin test and the reactors are sold subject to post-mortem inspection, the term "passed for food" does not mean that the animal was not tuberculous, but that the lesions of the disease were found in but a few places and small in size, and the meat therefore considered perfectly fit for food.

In this connection we quote from the Twenty-fifth Annual Report of the Bureau of Animal Industry:

"Under the inspection system the animals found tuberculous are disposed of in three classes, according to the extent of the disease. Carcasses which show very slight infection may often be safely passed for food after the removal of the lesions, the loss in such cases of course being small. Other carcasses, affected to a somewhat greater degree, but still not badly diseased, are allowed to be rendered into lard or tallow at a sterilizing temperature after all diseased portions have been cut away and condemned. In these cases the loss is more considerable. A third class comprises carcasses that are considered unfit for food in any form and are totally condemned. The loss on these is still greater, amounting in the case of cattle to about three-fourths of the cost. The salvage consists of the hide, grease, fertilizer, etc."

No. 1.—JERSEY COW.

August 29, 1910.			August 30, 1910					
2 P. M.	4 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.
102.4	102.0	101.8	103.2	104.4	104.2	101.4	100.8

Injected 9 P. M. August 29 with 2 c.c. tuberculin. High initial temperature accounted for by being led several miles on a warm day.

September 1, 1910				September 2, 1910				
8 A. M.	10 A. M.	12 M.	3 P. M.	8 A. M.	10 A. M	12 M.	2 P. M.	4 P. M.
100.0	101.2	101.4	101.2	102.0	101.6	101.6	101.6	100.8

Injected 9 P. M. September 1 with 5 c.c. tuberculin.

October 7, 1910	October 8, 1910

No. 1. The second test following the first with a two-day interval showed that two and a half times the initial dose of tuberculin failed to give a reaction. Five weeks later the ordinary dose of tuberculin gave no rise in temperature.

No. 2.—SHORTHORN COW.

August 26, 1910			August 27, 1910			
9 A. M.	12 M.	3 P. M.	6 A. M.	9 A. M	12 M.	3 P. M.
100.2	100.8	100.4	103.0	104.0	104.6	104.2

Injected 9 P. M. August 26 with 2 c.c. tuberculin.

September 2, 1910					September 3, 1910				
8 A. M.	10 A. M.	12 M	2 P. M.	4 P. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.
100.8	100.6	100.4	101.0	101.0	103.4	103.0	103.4	102.6	102.2

Injected 9 P. M. September 2 with 2 c.c. tuberculin.
Slaughtered September 17. Condemned.

No. 3.—SHORTHORN COW.

August 25, 1910			August 26, 1910			
9 A. M.	12 M.	3 P. M.	6 A. M.	9 A. M.	12 M.	3 P. M.
100.2	99.8	101.0	101.8	103.0	104.6	104.6

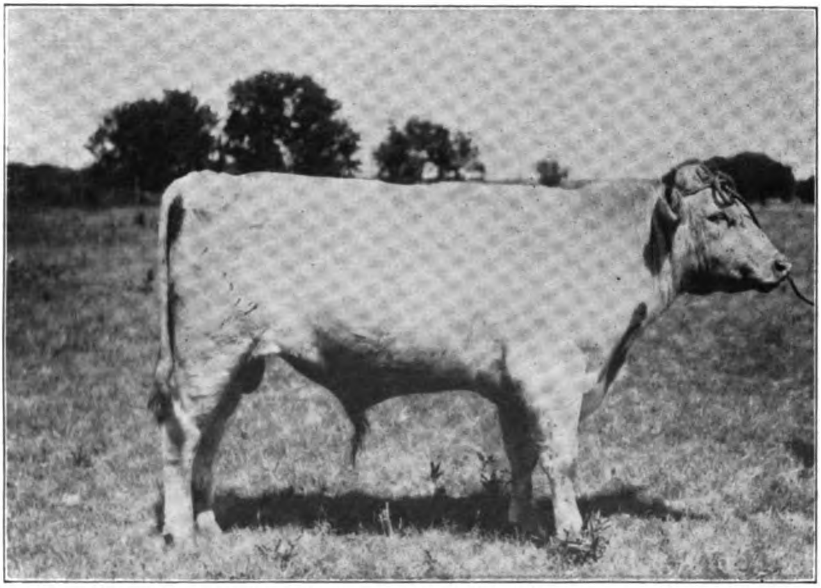
Injected 9 P. M. with 2 c.c. tuberculin.

September 2, 1910				September 3, 1910				
8 A. M.	10 A. M.	12 M.	2 P. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.
101.4	100.6	100.6	100.8	101.8	101.6	101.2	101.0	101.0

Injected 9 P. M. September 2 with 5 c.c. tuberculin.

of 2 c.c., gave a sufficient rise in temperature to have been called a reaction, if in a badly infected herd, while No. 3, with a second injection of 5 c.c., did not show any disturbance.

No. 4.—SHORTHORN BULL.



Slaughtered June 29, 1911. Tuberculous. Passed for food.

August 25, 1910			August 26, 1910			
9 A. M.	12 M.	3 P.M.	6 A. M.	9 A. M.	12 M.	3 P. M.
102.0	101.4	101.4	104.4	105.8	107.0	106.0

Injected 9 P. M. August 25 with 2 c.c. tuberculin.

October 7, 1910		October 8, 1910					
3 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	3 P .M.	6 P. M.
101.5	102.0	103.7	104.8	104.7	105.2	104.2	104.0

Injected 9 P. M. October 7 with 2 c.c. tuberculin.

October 14, 1910			October 15, 1910					
9 A. M.	11 A. M	1 P. M.	7 A. M.	9 A. M.	11 A. M.	1 P. M.	3 P. M.	5 P. M.
102.3	101.3	101.0	102.0	101.3	101.4	101.4	102 0	102.0

Injected 9 P. M. October 14 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M	10:30 A. M	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.4	101.2	101.1	105.0	105.3	105.3	105.4	104 3

Injected 8: 30 P. M. May 17 with 2 c.c. tuberculin.

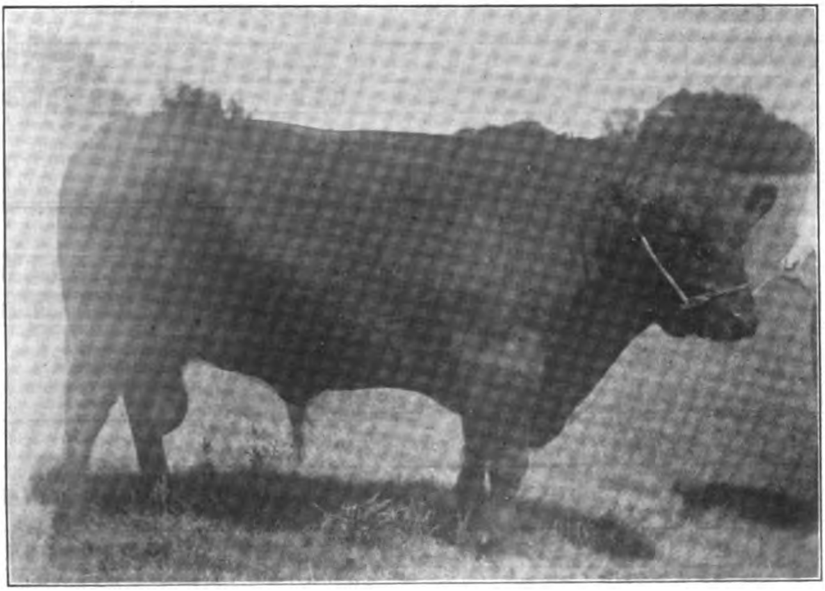
May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M
103.0	102.3	102.3	104.2	104.4	104.2	105.1	101.1

Injected 8: 30 P. M. May 19 with 6 c.c. tuberculin.
Slaughtered June 29, 1911. Passed for food.

No. 4 is from same herd as Nos. 2 and 3. The second test, six weeks after first, gave a typical reaction.

Seven months later a test with 2 c.c. of tuberculin gave a reaction. Immediately following this test an injection of 6 c.c. was given, which gave a positive reaction. The high initial temperature in the last test cannot be accounted for unless caused by the confinement.

No. 5.—ANGUS BULL.



Slaughtered June 29, 1911. Tuberculous. Unfit for food.

January 8, 1908		January 9, 1908		
2:30 P. M.	**4 P. M.**	**8:30 A. M.**	**11 A. M.**	**2:30 P. M.**
101.6	101.0	106.2	106.6	105.8

Injected 9 P. M. January 8 with 2 c.c. tuberculin.

December 23, 1908			December 24, 1908			
7 A. M.	**10 A. M.**	**1 P. M.**	**7 A. M.**	**10 A. M.**	**1 P. M.**	**4 P. M.**
101.0	101.0	101.6	104.8	105.0	105.8	104.6

Injected 9 P. M. December 23 with 2 c.c. tuberculin.

December 20, 1909			December 21, 1909			
8 A. M.	**10:30 A. M.**	**1 P. M.**	**8 A. M.**	**10:30 A. M.**	**1 P. M.**	**2:30 P. M.**
101.0	101.4	100.4	100.3	104.8	104.0	103.4

Injected 9 P. M. December 20 with 2 c.c. tuberculin.

October 7, 1910		October 8, 1910					
3 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	3 P. M.	6 P. M.
101.4	102.5	102.0	102.4	103.0	104.2	103.9	103.5

Injected 9 P. M. October 7 with 3 c.c. tuberculin.

November 14, 1910			November 15, 1910					
8 A. M.	10 A. M.	12 M.	6 A. M	8 A. M.	10 A. M	12 M.	2 P. M.	5 P. M.
100.8	101.2	100.6	101.0	101 5	101.8	101.4	101.4	101.9

Injected 9 P. M. November 14 with 4 c.c. tuberculin.

May 17, 1911			May 18, 1911					
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.	6 P. M.
100.1	100.4	100.4	101.2	101.2	101.1	101.3	103.0	102.1

Injected 8:30 P. M. May 17 with 3 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M	1 P M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.0	103.0	103.0	103.2	105.2	104.4	104.4	103.0

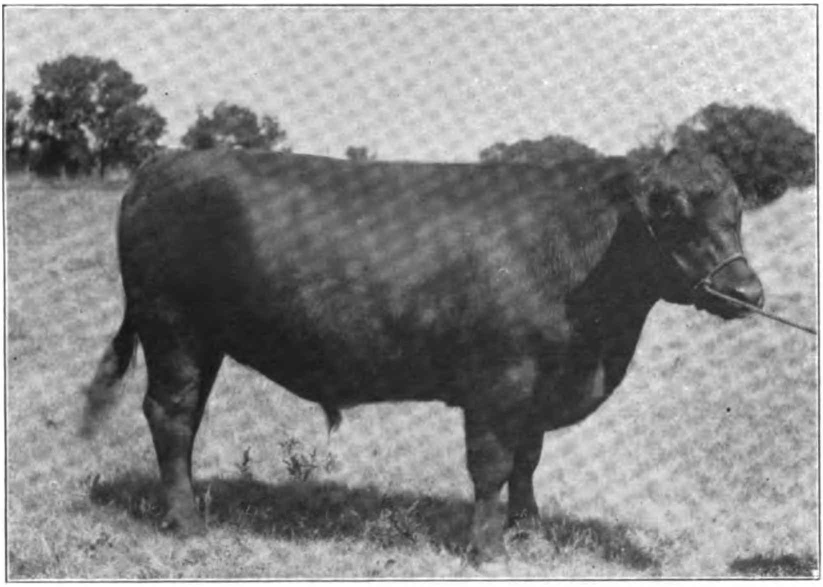
Injected 8:30 P. M. May 19 with 8 c.c. tuberculin.
Slaughtered June 29, 1911. Condemned.

No. 5 was a bull weighing over a ton, of fine type, and during the whole period easily kept in good flesh. Found tubercular early in 1908, he gave each year a typical reaction until October, 1910, when the rise in temperature was less than 2 degrees. Thirty-seven days later with an injection of 4 c.c. of tuberculin his temperature remained normal. Six months later he gave a reaction that would not have been considered positive. The rise to 103 at 4:00 P. M. would not have been discovered in the course of an ordinary test as the four previous temperatures would have been considered sufficient.

This case is interesting from the fact that there was evidently a considerable period when this animal would have passed a careful test as being perfectly free from tuberculosis.

The high initial temperature in the last test was probably caused by the confinement.

No. 6.—ANGUS STEER.



Slaughtered June 29, 1911. Tuberculous. Passed for food.

December 20, 1909			December 21, 1909			
8 A. M.	**10:30 A. M.**	**1 P. M.**	**8 A. M.**	**10:30 A. M.**	**1 P. M.**	**3:30 P. M.**
102 0	101.4	101.4	104 6	106.4	106.8	106.0

Injected 9 P. M. December 20 with 2 c.c. tuberculin.

October 7, 1910		October 8, 1910				
3 P. M.	6 P. M	6 A. M.	8 A. M.	10 A. M	12 M.	3 P. M.
101.3	100.7	103.5	105.2	105.5	105.4	104.8

Injected 9 P. M. October 7 with 2 c.c. tuberculin.

October 9, 1910			October 10, 1910				
9 A. M.	11 A. M.	1 P. M.	7 A. M.	9 A. M.	11 A. M.	1 P. M.	3 P. M.
101.0	101 0	100.6	102.1	101.7	102.0	101 9	101.3

Injected 9 P. M. October 9 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M	5:30 A. M.	8 A. M	10:30 A. M.	1 P. M.	4 P. M.
101.3	101.3	100.4	102.3	101.2	103.0	103 0	101.0

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

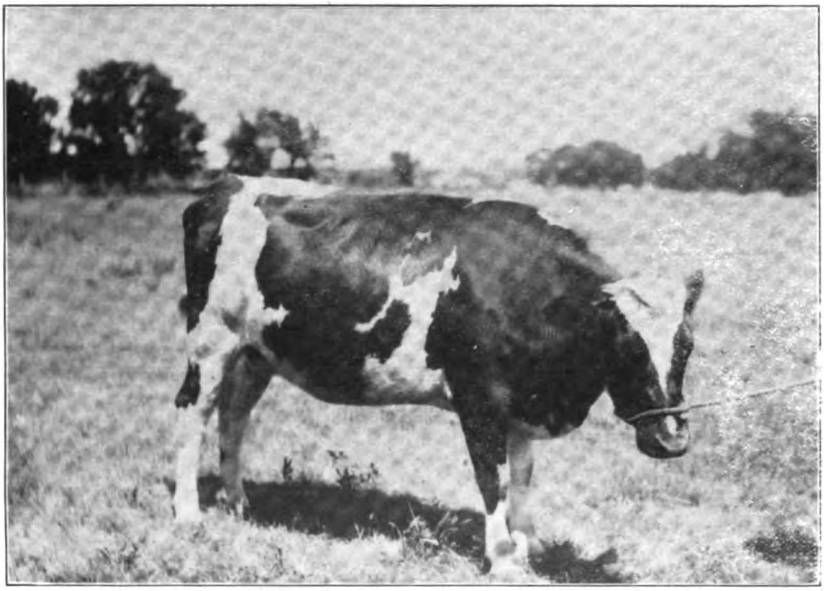
May 19, 1911			May 20, 1911				
8 A. M	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	3 P. M.
101.0	101.0	101.1	104.2	104.3	104.3	105.0	105.0

Injected 8:30 P. M. May 19 with 8 c.c. tuberculin.
Slaughtered June 29, 1911. Passed for food.

No. 6. This steer was part of the show herd at the International Live Stock Exposition in 1909 and was found tubercular at the yearly test a short time after. This is another case where with an interval of six months between tests there was no positive reaction; however, there was enough rise in temperature to make the case a suspicious one. (Test of May 17, 1911.)

This animal gave no reaction to 2 c.c. of tuberculin injected October 9, 1910, this being nullified by the 2 c.c. of the test two days before.

No. 7.—AYRSHIRE HEIFER.



Slaughtered June 29, 1911. Tuberculous. Unfit for food.

December 22, 1910			December 23, 1910			
6 A. M.	8 A. M.	10 A. M.	6 A. M.	8 A. M.	10 A. M.	1 P. M.
101.6	102.6	100.6	105.2	106.4	106.0	105.4

Injected 9 P. M. December 22 with 2 c.c. tuberculin.

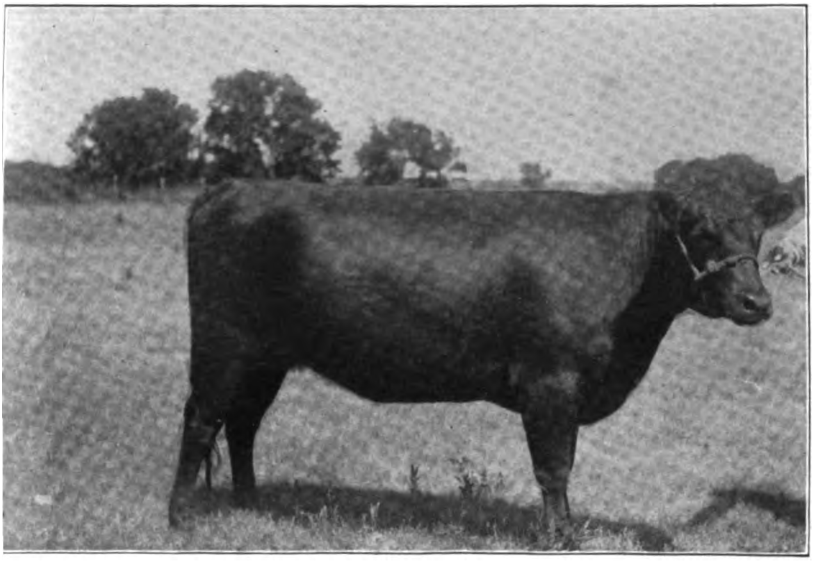
March 21, 1911			March 22, 1911				
2 P. M.	4 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.
101.4	101.0	101.6	102.8	104.8	105.6	105.2	102.4

Injected 9 P. M. March 21 with 2 c.c. tuberculin.

March 27, 1911			March 28, 1911				
2 P. M.	4 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M	12 M.	2 P. M.
101.8	101.2	101.0	103.6	104.8	105.2	103.6	101.6

Injected 9 P. M. March 27 with 6 c.c. tuberculin.

No. 8.—ANGUS HEIFER.



Slaughtered June 29, 1911. Tuberculous. Passed for food.

December 27, 1910			December 28, 1910			
:30 A. M	11 A. M.	1:30 P. M.	6 A. M.	8:30 A. M.	11 A. M.	1:30 P. M
101.2	102.0	101.4	103.0	104.6	105.0	103.8

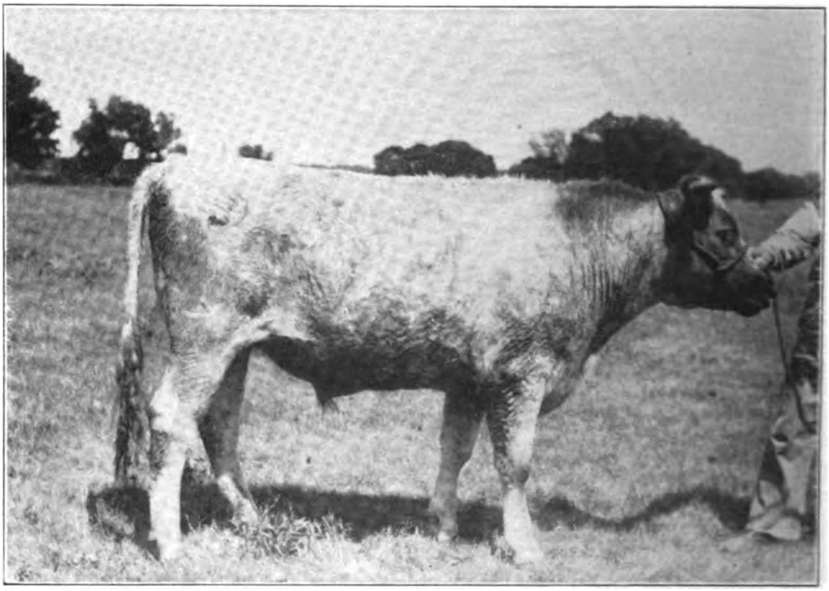
Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
A. M.	10:30 A M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.4	100.6	101 8	103.2	103.8	103.0	102.6	102.0

Injected 9:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911	May 20, 1911

No. 9.—SHORTHORN STEER.



Slaughtered June 29, 1911. Tuberculous. Passed for food.

December 27, 1910			December 28, 1910			
8:30 A. M.	11 A. M.	1:30 P. M.	6 A. M.	8:30 A. M.	11 A. M.	1:30 P. M.
102.0	100.6	101.8	102.6	103.2	105.2	104.8

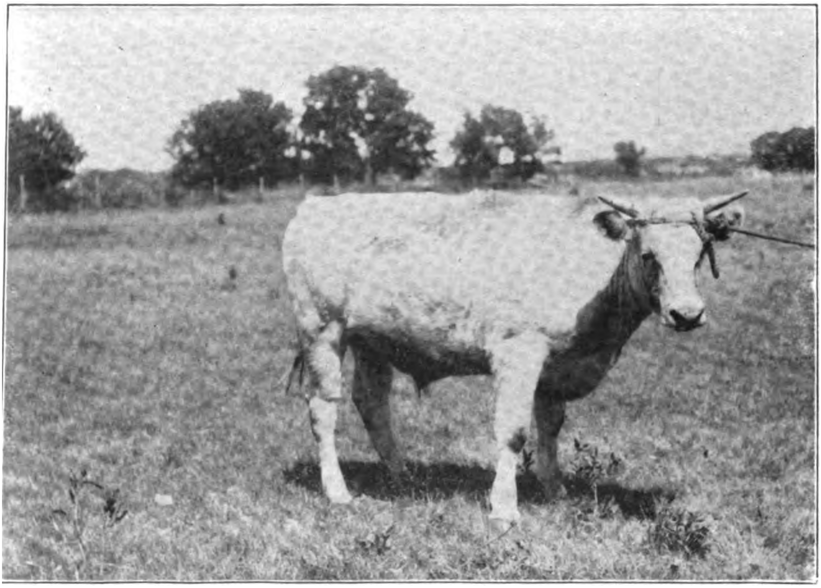
Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
102.4	102.8	102.4	103.0	103.6	103.6	103.0	103.6

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911	May 20, 1911

No. 10.—SHORTHORN CALF.



Slaughtered June 29, 1911. Tuberculous. Passed for food.

December 27, 1911			December 28, 1911			
8:30 A. M	11 A. M.	1:30 P. M.	6 A. M.	8:30 A. M.	11 A. M.	1:30 P. M
101.6	102.4	101.6	104.0	105.2	106.4	106.0

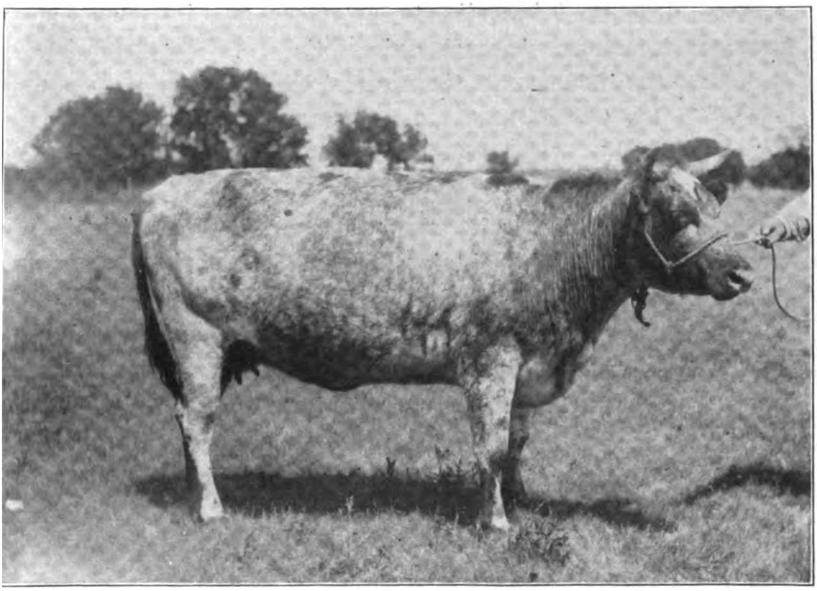
Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
102.6	101.8	101.8	103.2	105.8	106.2	106.4	105.6

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911	May 20, 1911

No. 12.—SHORTHORN COW.



Slaughtered June 29, 1911. Tuberculous. Unfit for food.

December 27, 1910			December 28, 1910			
8:30 A. M.	11 A. M.	1:30 P. M.	6 A. M.	8:30 A. M.	11 A. M.	1:30 P. M.
101.8	101.2	101.0	102.2	105.0	105.0	106.4

Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
102.0	101.0	101.2	101.8	102.2	103.6	104.2	104.0

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911				
A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.

Nos. 8, 9, 10, 11, and 12 show the effect of giving a largely increased dose of tuberculin to overcome the influence of the previous injection. In each animal the 6 c.c. was sufficient to overcome the influence of the 2 c.c. That this is not constant is shown in the test of Nos. 1 and 3, where, with the second test following within a week, 5 c.c. failed to give a reaction over the 2 c.c.

It is realized that with the small number of cattle in this experiment the results obtained are not conclusive, but enough data are at hand to show that it is quite possible to nullify the tuberculin test by the prior injection of an ordinary dose of tuberculin; also that the influence of an ordinary dose will last more than 30 days, and that a reliable test can not be expected within 60 days. Doubling the previous dose of tuberculin will usually give a reaction, but this is not sufficiently constant to be relied upon.

It is also shown that an animal may give one or more positive reactions and months later may not react.

SOME INVESTIGATIONS OF THE CEDAR RUST FUNGUS,
Gymnosporangium juniperi-virginianae

BY GEORGE HERBERT COONS

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SOME INVESTIGATIONS OF THE CEDAR RUST FUNGUS,

*Gymnosporangium juniperi-virginianae**

BY GEORGE HERBERT COONS

PREVIOUS WORK ON SPORE EJECTION

It has been recently shown by Buller 1909 that the basidiospores of various *Hymenomycetes* are ejected from their sterigmata. The purpose of this paper is to describe a similar condition found in a rust, *Gymnosporangium juniperi-virginianae* Schw., and to discuss the possible bearing of these observations.

That spores were ejected from *Basidiomycetes* with great force had long been suspected and much written about and, as it happens, with more fancy than fact. Bulliard 1791 (p. 51) observed that there was a dispersal of spores from certain *Agaricaceae* in other directions than vertical. Hoffman and De Seynes confirmed the observations of Bulliard by placing a mushroom on its side and noting that the spores were found at some distance from the pileus. MacBride 1885 called attention to a similar observation in which mushrooms under a bell jar dusted over the whole enclosed area.

The white clouds of spores which, rising, look like smoke were often noted in *Polyporus* sp. and had been taken to confirm the idea of forcible ejection of spores. Among the first workers on this genus was Hoffman, who found that if he hung fruiting bodies of *Polyporus destructor* and other *Hymenomycetes* under a bell jar the spores were distributed over a greater circumference than that of the pileus.

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* The department of Agricultural Botany has for some years been

Brefeld described two types of spore ejection. The first of these was described for *Coprinus stercorarius* (Brefeld 1877, p. 65) and in this he describes the ejection to a great distance, relatively speaking. The spores were shot off simultaneously and a small drop of fluid left on the sterigmata. The other type of ejection was described for *Amanita muscaria* (Brefeld 1877, p. 32), and this description has been largely overlooked and only the former description quoted as Brefeld's observation. But in this last case Brefeld states that it is by weak ejection that the spores are freed and drop down in the small chamber between the lamellae.

A writer who has been largely overlooked in this connection is Zalewski 1883, who repeated Brefeld's observation, using other species, and who was, in the main, able to confirm the ejection, but not the details as Brefeld saw them. The observations he made are summed up in the following quotation here given in English since the original work may not be readily available.

> "According to this author (Brefeld), all the sterigmata of a given basidium of the fungus simultaneously burst open at the apex, causing the escape of a portion of the contents of the basidium, which collapses, and the spores are thrown off with some force.
>
> "The experiments of this author have been repeated by me on various *Hymenomycetes,* including species of *Agaricus, Coprinus* and *Russula* and *Cantharellus cibarius.* In most cases his results have been confirmed, tho in only a few cases have I been able to witness the discharge of all four spores at once; generally I noted the discharge of one, two, or more rarely three, spores from their sterigmata. In one case two spores were discharged from the basidium of an *Agaricus,* while the other two spores remained attached.
>
> "Brefeld reported that a drop of fluid remained attached to the sterigma after the discharge of the spore. I have never seen this, tho in all cases I have observed a thin streak of fluid following the discharged spore, but no drop of fluid remained attached to the sterigma. Following the discharge of the spores, with the fluid mentioned, the basidium generally collapsed somewhat on one side.

"With the apparatus available I was unable to see any opening remaining at the apex of the sterigma after the discharge of the spore. Perhaps in *Hymenomycetes*, such as *Corticium amorphum*, with large basidia and large spores, this would be possible. The species observed by me had small spores and this opening was evidently quickly closed after the spore discharge, perhaps due to the elasticity of the wall of that part of the sterigma. There can, however, be no doubt that the apex of the sterigma is open at the time of the spore-discharge.

"The discharge of one spore after another from a given basidium would be quite impossible were it not for the closing of the opening in the sterigma either thru the contraction of the membrane or the lodging of some granular material in the opening."

Zalewski's work is worthy of note because he undoubtedly observed the ejection of spores in a great many species of *Agaricaceae*, as well as in lower fungi.

To this list of earlier workers and to those who reported the same sort of ejection of spores the name of Hansen should be added. Hansen reported for *Agaricus* (*Stropharia*) *semiglobatus* the same sort of ejection as Brefeld had reported for *Coprinus stercorarius*. This form ejects its spores at night mostly, only a small fraction being ejected during the day. A fruiting body whose whole stipe was 60 mm. cast its spores 100 mm. He cut a portion from the darkened side of a mushroom and noted that the figure cast was also notched. From this he concluded that the greatest ejection came from the darkened side.

There were then two sorts of spore ejection so far described, the one which dealt with a very strong force by which the spores were shot many centimeters, and the weak ejection in which the spores merely cleared the projecting parts of the lamellae.

The work of Falck in 1902 and 1904 was very clear. Falck found only the weak ejection, and in experiments to determine the other sort of ejection he found only a downward fall of the spores. But his experiments throw great light on the records of Bulliard and Hoffman and De Seynes. And it is interesting to note that Falck used the beam of light method, later devised independently by Buller. Falck found that the spores were spread evenly about an enclosed chamber from the pilei, and this spreading was not due to a projective force on the part of the mushroom, but due solely to air currents. In this the light and heat relations are the ones especially operative. The ejection is independent of light and gravity, but is stopped by chloroform. Following the ejection the spores fall vertically from their weight until caught up by the swirls of air. By means of insulated chambers Falck was able to prove the generation of heat by the hymenial layer—in some cases the rise in temperature amounting to 6 degrees. By these temperature differences the currents are engendered, and, while not noticeable as currents, they are nevertheless effective in dispersal. Falck discusses this method of liberation for the rusts and shows that when *Gymnosporangium juniperinum* is put in a closed chamber the spores are spread thruout. He discusses the significance of this in the production of infection from material upon the ground.

The real proof of the ejection of spores of the *Hymenomycetes* was furnished by Buller 1909, who was able to demonstrate by a series of careful experiments the ejection and fall of spores. For this he devised a method of determining whether spores were falling, by means of a beam of light—a device by which it is possible to see the individual spores moving about quite like motes in the air. Then by cutting small sections of the lamellae of mature mushrooms and mounting in a closed chamber he was able to observe directly with the microscope the ejection and fall of spores.

issuing from the still air between the gills, the spores are caught by eddies of air and swirled here and there, their weight, however, making them gradually settle to the substratum.

Considering the relation of the spores to the lamellae—that the space between the lamellae is narrow and comparatively speaking extremely deep,—it is of course impossible for the spores to emerge from the inner portions of the gills in any other direction than downward, and it is also obvious that the shooting phenomena described by Bulliard and others were due to air currents—a thing not reckoned with perhaps on account of the fact that the extreme lightness of the spores was not realized.

LIFE-HISTORY OF CEDAR RUST FUNGUS

Gymnosporangium juniperi-virginianae Schw., as is well known from the work of Farlow 1880, 1886; Halsted 1886; Pammel 1905; Sanford 1888; Heald 1909, and others, is a parasite on *Malus* and *Pyrus* spp., on which it forms its aecial stage, and on *Juniperus virginiana*, where it develops its telial form.

The basidiospores from the cedar infect the apple by penetrating the cuticle. Since a statement that the infection takes place thru the stomata inadvertently crept into the paper by Heald 1909, it was thought well to determine the nature of the infection procedure.

Sporidia were sown on the leaves of young "Wealthy" apple grafts, in a drop of water, and the plants kept under bell jars. In five cases the spores were put only on the upper surfaces of the leaves, and in five on the lower surfaces only. Five plants were kept as checks. Greater infection, i. e., production of pycnia and aecia, took place in the cases where the sowings were on the upper surface of the leaves. Since the apple presents few if any stomata on the upper leaf surface, it is evident that the germtubes of germinating sporidia penetrate the cuticle. With the microscope it was possible to see the hyphae from the sporidia, after a vagrant, tortuous growth in the water, bend sharply downward at the edge of the drop and pass into the cells beneath. This last observation was made with leaves washed in sterile water and kept in Petri dishes. These were inoculated in drops of water and marked by circles with the cork borer. Some success was had, too, in inoculation of small green apples.

This observation is quite in harmony with the generalization of Evans 1906, who found that basidiospores penetrated directly, and urediniospores and aeciospores enter thru the stomata.

Heald 1909 showed that the mycelium is perennial in the red cedar, for the galls begin to appear on the twigs before the opening of the aecia—hence the infection that shows up is due to the spores of preceding year. While the actual infection has never been observed, or produced artificially, it is evidently a leaf infection, for the leaves of different stages of swelling can be found. usually showing a swollen center (figs. 1 and 5), or at times a greatly enlarged base with the split portions of the epidermis at the top of the gall.

These galls increase in size during the growing season and in December show small depressed areas. In these the beginnings of the teliospores may be sought. In March these areas begin to show growth; small protrusions gradually occur and as the epidermis finally splits the developing sori emerge. This continues until the sori have reached a length of 5 to 7 mm. (fig. 3).

In the spring, following warm wet weather, these sori swell to from five to ten times their length and increase in diameter at least four times. (Fig. 2.) It is found that they are hollow and that the gelatinous matrix is capable of swelling again and again after drying.

cerned is the teliospore phase and the succeeding stage, and these therefore will be described in detail.

The teliospores of rusts are characterized generally by being thick-walled, and by the permanent pedicel. (De Bary 1887, p. 279.)

The formation of teliospores has been described in detail by Blackman 1904 (p. 344) for *Gymnosporangium clavariaeforme*. Here it is found that the hyphae, after forming a layer, produce binucleate, rectangular cells which in turn develop several narrow outgrowths. These outgrowths have paired nuclei and undergo two divisions. By these divisions cells are differentiated from the pedicel. The teliospore walls thicken and its cells become filled with an oily reserve material.

In *Gymnosporangium juniperi-virginianae* the teliospores are formed by December and at this time various sizes and stages of telial growth are visible. Sori examined at this time showed depressions marking the location of sori, and a section thru a sorus shows the teliospores all in the same plane. This continues until March, during which month the sori protrude from 5 to 7 millimeters. Sections thru these lengthened sori show that the outer layers of spores are short pedicellate and the succeeding ones longer as one passes inward, and the spores occur only on the surface of the sori, altho there may be several layers of them. This variation in growth and the arrangement is explained by Farlow as a reaction to light and air. (Farlow 1880, p. 10.)

Necessarily such a method of development produces a tubular sorus.

The teliospores are thick-walled and two-celled. The color is orange and is due to the granular contents and the oil. Occasionally in the inner layers of the sorus a spore is found that is thin-walled and somewhat hyalin. Its exact nature has not been worked out. (Blackman 1904, p. 330.)

Very large and distinct oil drops are present in all spores. Sanford 1888 mentions their presence in the mycelia in the gall. In the early stages of the sorus these drops are circular and are scattered thru the cell. At later stages and in old teliospores these drops coalesce. This is the condition that is shown in dried specimens.

The function of this storage of oil will be dealt with under nutrition phenomena.

The sori of *Gymnosporangium,* as has been said, when wet swell considerably. Then the spores, at ordinary temperature, put forth the promycelia. Farlow states that four germ tubes per cell are produced by this species but no spore has been observed by the writer to develop more than two for each cell and one is a more common number. The process of putting out germ tubes requires from 6 to 15 hours in contrast to "less than 3 hours" as reported by Blackman 1904 (p. 330), for another species of *Gymnosporangium.* Into these germ tubes the granular contents of the cell pass. In one hour the germ tube becomes marked off into four cells, and in another hour spores are produced upon small sterigmata. The granular material of the germ tube passes into the spores but the germ tube remains turgid.

Under certain conditions of moisture and temperature neither spores nor germ tubes are produced. (Heald 1909, p. 108.) An extrusion of the plasm of the cell takes place, which in turn can send out a mycelial tube and probably produce infection. Material gathered on a very cold and rainy day showed in every one of 100 mounts from different sori an absence of normal germ tubes and a great abundance of these so-called abnormal forms.

Some tests were made to determine if the gaseous surroundings had anything to do with the formation of the germ tubes. Spores about to germinate were prevented from germinating by growths of germ tube and absence of sporidia when the spores germinated under water. Sappin-Trouffy 1896 (p. 59), working with *Puccinia malvacearum,* found that submerged promycelial cells separate and put out germ tubes—which must be exposed to air before sporidia are formed.

Frequently on a normal germ tube three spores are produced and the fourth sterigma will protrude, growing perhaps five times as long as the others. Such a case was observed from spores planted on an apple leaf, and this elongated sterigma penetrated the cuticle of the host directly. The spores germinated and produced a rather wavy, thin-walled hyphal net on the surface. It would seem that the germ tube was capable of making a quicker infection than the spores.

In the great majority of cases the promycelium bears four spores upon one side on long sterigmata. When these are formed, the long germ tubes are turgid but entirely void of granular contents. The sterigmata, too, are hyalin. The sterigmata are very pointed and the spores show a prominent "tail" where they are connected.

THE SIZE OF SORI AND TELIOSPORES

The size of cedar-apples varies greatly. Heald 1909 ascribes this to light or heavy infection. It seems, however, rather to be dependent upon the trees, for certain trees of a given locality are always more severely affected than others. However, it is noticed that when practically every branch has a gall the galls are small, but where the effect is scattering the galls are larger.

There are some galls so small that they can accommodate only one or two sori, and there are others on which as many as one hundred are borne. (Fig. 4.) The galls vary in size from 1 mm. in diameter to 5 cm. The prevailing shape is reniform, due, Farlow holds, to the unequal growth of the basal and outer cells.

Sori are usually from 1 to 2 mm. apart and until they are very much swollen do not touch each other. As has been said, they are very hygroscopic, as is shown by the following table made from measurements taken after soaking the sori for 30 minutes:

TABLE 1.—*Comparison of average dimensions of sori, when dry and when wet.*

Length		Diameter			
		Base		Tip	
Dry	Wet	Dry	Wet	Dry	Wet
7 mm.	13 mm.	1.5 mm.	6 mm.	1 mm.	2.5 mm.

The spores, too, show an increase in size, especially in the pedicels, as is shown by the following table. About 50 spores were put on a slide. These were measured dry. From these spores the wet mount was made and the measurement made after 30 minutes.

TABLE 2.—*Comparison of average dimensions of teliospores, when dry and when wet.*

Width		Length		Diameter pedicel	
Dry	Wet	Dry	Wet	Dry	Wet
15.2 mu	16.5 mu	43.4 mu	48.1 mu	2.8 mu	4.7 mu

Here length and width increase slightly; but the gelatinous pedicel increases nearly 60 per cent. In spite of this great hygroscopic power, the greater part of the increase in bulk of the sorus arises from the jelly-like matrix in which the pedicels are embedded.

The effect of this swelling on the exposure of the sporidia to the wind is, of course, manifest. Each germ tube is accommodated and the adhesion of the spores of adjacent tubes prevented. A view of the sorus when the germ tubes are all extended presents an abatis of sterigmata and spores. The germ tubes are not evident. They are found, however, curling along the sorus, with the sterigmata growing at right angles. This would seem to be a hydrotropic response.

While in the cedar-apple there is no such large increase of hymenial surface as is found in the *Hymenomycetes* (Falck 1904; Buller 1909, p. 31), yet we have here no mean device for spore dispersal.

SPORE DEPOSITS

It is possible to make spore prints from the sori of *Gymnosporangium* quite as one would make them from the pileus of a mushroom. Air currents must be avoided and drying prevented. This latter condition is more difficult to obtain than with the pileus of a mushroom.

That the spore prints of a mushroom are very beautiful is due to the fact that the spaces between the fan-like gills are reproduced. In the rust we have no such design to follow and so along the length of each sorus a bright orange-colored pile accumulates. A cross-section of a gall including several sori gives a figure comparable to the spore prints from a mushroom fungus. By cutting a sorus transversely and setting it up on end over a pin, or upright support, it is possible to get a ring deposit all around the sorus.

The spores are very adhesive and it is not possible to determine any arrangement in the piles of spores.

These spore prints form an easy way to secure a pure culture of spores for inoculation, since it is possible to secure them upon sterile glassware, free from the moulds, etc., that are invariably present on the sorus, and in infusions made from the sorus.

MACROSCOPIC OBSERVATIONS ON THE SPORE DISCHARGE

Following Buller's device of a beam of light to make the movement of spores visible, results similar to his results on *Agaricaceae* were obtained. However, in dealing with this spore body that was more subject to drying, no such long duration of spore dissemination was observed. However, the phenomenon of reviving noticed by him with reference to xerophytic forms was noticed in *Gymnosporangium*, but of course after no such long intervals.

In brief the method followed was this: A gall showing sori well extended and pulverulent with the sporidia was pinned to a sheet of cork over a beaker. A beam of light from an electric arc, passed thru the condensers and a cooling bottle, was sent thru the chamber. Immediately the appearance of motes in the air was observed but all the bodies were the same size. These did not seem to be falling, but were rather swirling about in the air.

Their origin could be traced very readily to the sorus where the number in the air was always larger. The movement of the spores were quite that of the pappus of a thistle in a light breeze. In general one could make out a movement downward.

Here an interesting observation was made. It was noted that a beaker left over night became coated with a yellow deposit. If a large gall was pinned up, the yellowing, while thicker on the bottom, was evenly distributed about the sides. But with a one-sided pinning of the sorus or a drying or injury to one side the beaker became manifestly coated on but one side.

The greatest length of time that the spore fall was observed to continue was two hours, but this same preparation showed next morning a strong yellowing of the sides and bottom of the beaker. Evidently the drifting had taken place for a greater length of time. In the morning no discharge of spores was noticeable.

This same preparation placed in water immediately swelled again and began a spore discharge. Such alternate drying and revival was made three times in all. At the last time there seemed no diminution in the amount of the discharge.

Five months afterwards an attempt was made to revive some galls by soaking them. These were galls that had been collected before the germ tubes were extended. All these attempts were unsuccessful. Perhaps the change in the oil content had something to do with this. This last attempt at revival is, of course, not comparable to the revival of xerophytic species dealt with by Buller 1909 (p. 105), since the forms are not in the same stage.

THE EXTERNAL CONDITIONS AND THE SPORE DISCHARGE

Light seemed to have no effect on the spore discharge, since it took place either in the daylight or at night, as the piles of spores testified.

Humidity, so long as the promycelium tubes were not desiccated, showed no effect, but the experiments with this were very meagre. The only attempt to affect the humidity was by using a moist beaker and another with the air dried by several grams of $CaCl_2$. For 10 minutes the discharge was observed under each condition, and even following the replacing with the moist beaker no sensible decrease or increase of the number of spores flying was noted.

Temperature and its effects were noted but briefly. The preparation discharges at several degrees above room temperature—the air in the beaker being heated to 30° C. several times in the experiments. A preparation that was discharging spores at room temperature was put into the ice box (7° C.) for 10 minutes and then returned to the beam of light. Spores were discharged as before.

With anaesthetics the same general results that Buller noted were found. A few drops of chloroform were allowed to disappear from the glass and then immediately the sorus was placed in the impregnated atmosphere. Discharge from the sorus ceased immediately. With ether a similar result was obtained.

These results will be discussed in the portion devoted to the Mechanics of the Spore Discharge.

THE PROJECTION OF SPORES

Exactly as he found the spores of *Hymenomycetes* to be very adhesive, I found that those of *Gymnosporangium* were likewise, so that if spores were discharged against glass or paper it was fairly impossible to dislodge them. Two spores touching upon the glass after a discharge would draw together and a third and even a fourth would be drawn into place. Hence on the glass when spores were falling, constant readjustment of spores was taking place.

METHOD I

In the sorus of *Gymnosporangium* it was found that the spores were produced equally upon all sides. A cross section of this spore mass was made which gave a ring of gelatinous substance with the edges almost vertical. This was placed in a moist chamber slide and covered with a cover glass. With the low power it was possible to see the spores on the sterigmata. bristling out about the whole surface.

Exactly as Buller describes, the apparent shooting of the spores could be seen, not as a distinct view of the spore but as a streak of yellow across the view. This could be traced back to the vacated sterigmata. Focusing downward it was possible to find the heaps of spores some distance, 200 mu, from the sorus. Without Buller's convincing proof of the optical illusion in looking at vertical objects with the microscope,* the streak would have been interpreted as the projectile path of the spore. But it was undoubtedly the downward fall of the spore that was seen. Watching the spores with this in mind it was evident that the streak began a sensible distance from the sorus.

METHOD II

This method as used in the case of *Gymnosporangium* consisted in placing one of the active sori horizontally in the moist chamber slide. Then the low power was focused just above some sterigmata. Here it was found that spores springing into view are seen perfectly for an instant and then disappear. The waits were long with this method and the best results were obtained by focusing on the edge of the sorus.

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* Objects with vertical sides appear to have a trapezoidal shape, hence the spores falling downward appear to be traveling outward.

METHOD III

This method consists essentially in watching the basidia from which the spores are discharging. As in method II, the points of observation selected were at the edges of the sorus and were carefully watched for an hour or so. The eye after following the irregular surface sets up certain landmarks and any change in the topography is noted. Hence it was easy to find areas on the sorus from which spores were being discharged.

As near as could be judged with reference to the origin of the spores as to germ tube, those from a promycelium disappear singly, but within a short time of each other. The sterigmata after the discharge show no collapse but a slight rounding off of the pointed tip. This same rounding off of the pointed attachment was noticeable in the spores.

METHOD IV

This consists in watching the deposit of the spores on the glass about the sorus, having the basidia in focus at the same time. This preparation was in the moist chamber as before, but a very thin ring of the substance was taken. It was possible to have a hazy view of the promycelium and the spores, and where at the start in that particular field only 5 spores were scattered on the glass, at the end of 30 minutes some 40 or 50 were piled up. These occupied a swath about 100 mu wide. The distance of the innermost spore of this pile from the base of the sorus was 260 mu. This measurement was made with the low power. It represents therefore the distance that the spores were expelled. Those spores on the outer edge of the pile were projected 50 to 100 mu farther. Since the spores average about 20 mu in diameter they were projected from 13 to 18 times their length.

It was a most fascinating sight to see the spores arrive and immediately bring about a rearrangement of the positions. It was quite like the bursting of one bubble in a dish, whereupon all the other bubbles rearrange themselves. It was possible by a sharp focus upon the slide to see the "streak" (fall) and the sudden appearance of a new spore.

Methods I, II and III were repeated on a succeeding day with fresh material from the field. Method IV was possible only the first day and hence only one measurement can be given.

There can be no doubt that *Gymnosporangium juniperi-virginianae* Schw. expels its spores as is described for *Hymenomycetes.*

THE MECHANICS OF SPORE DISCHARGE

Brefeld's observation 1877 on the ejection of the spores of *Coprinus* with the subsequent exudation of a drop of water from the sterigmata led him to classify the phenomena with the ejection of spores or spore masses in *Empusa* or *Pilobolus.*

Zalewski 1883, whose results have been quoted rather fully, did not find that the spores were ejected simultaneously as a rule, and could see no exudation of the liquid contents of the basidium, but on the contrary he saw a thin stream of water squirt out and follow the spores. Inasmuch as Buller 1909 has shown that the actual projection is probably too rapid to be seen, and the streak that is seen is the downward path of the spore—appearing by optical illusion as an outward passing—Zalewski no doubt interpreted this as a streaming of a fluid after the spore.

To explain in general the cutting off, and in many forms the ejection, of spores, Zalewski stated that the middle lamella of the wall cutting off the spore gelatinized thru the influence of moisture, allowing the spores to fall or spring off. His observaplanation of the ejection of conidia from the lower forms, but explains the action as the result of twistings and torsions of the dried sporophores due to humidity changes. With reference to the *Hymenomycetes* Zalewski confessed that the sterigmata were too small to allow the hole that Brefeld postulated to be seen, and he was forced to suppose that the sterigma and spore had each of them an elastic membrane which closed the opening, or as an alternative, that the sterigma and spore had very thick and gummy protoplasm. But in his labored explanations he is seeking to harmonize the actual observations which he made with those of Brefeld, for in no case did Zalewski note an exudation of droplets of water. It is not clear why—after Zalewski had shown fairly conclusively that the spores of the lower fungi dropped off due to a hydrolizing of the middle layer—he could not have brought that over for use in the explanation of the cutting off of spores in the higher group. Except of course he had the squirting of the stream of fluid to account for.

Nowakowski gives for *Empusa grylli* the mode of cutting off such as Zalewski describes for *Empusa*, *Peronospora*, and other forms but in addition shows that the force of ejection is furnished by the simultaneous bulging of the walls of the columella and spore. Nowakowski, however, does not utilize the suggestion of Zalewski as to the hydrolysis and subsequent gelatinization of the middle lamella.

Buller inclines to the explanation given by Nowakowski but states that cytological work is necessary to prove the presence of the double wall or of any wall between the sterigma and spore. It is commonly supposed that such a wall is present in the *Basidiomycetes*, and De Bary figures it for *Corticium amorphum*.

It seems evident that the ejection of spores in *Gymnosporangium* is of the same sort as the ejection of spores of the *Hymenomycetes*. It is the ejection of turgid spores from a turgid basidium. The fact that chloroform and ether are able to stop the ejection seems to show that the phenomenon is one dependent upon protoplasmic activity, unless vapors in some way affect the turgor relations. The spores leave one after the other and there is no collapse of either spores or sterigmata. On the contrary there is a rounding off of the sterigma and a gradual disappearance of the projection on the spore—quite as if the two parts were rounding off in response to a turgor pressure, after the restraining connection was broken. The explanation of Nowakowski therefore seems to be tenable.

DISCUSSION OF PHYLOGENY

The work here reported is not startling in that it does not bring out the need for anything new in arrangement, but it is gratifying in that it verifies the result of keen observation by Tulasne, sixty years ago. We must, therefore, understand the various positions assigned the rusts in the development of the study of fungi.

Tulasne 1853 placed the *Uredinales* close to the *Hymenomycetes* on the basis of the homology of the basidium and the germ tube, to which latter he gave the name promycelium.

Brefeld 1888 first placed the *Uredinales* very close to the *Ascomycetes* but later he has taken the position of De Bary, and in this he is followed by the leading mycologists.

De Bary 1853 united the aecial forms with the lichens, and the "*Uredinales*" of that time he placed with the *Hymenomycetes*, following Tulasne. Later with the connecting of the aecial stage and the other spore forms—for which he is largely responsible—he placed the group between the *Ascomycetes* and the *Hymenomycetes*. In this he traces out a homology in the teliospores and the sporiferous parts of the *Agaricaceae* and a homology between the aecium and the ascocarp. With the former only are we concerned here. In his Comparative Morphology 1887 he says:

"The statements made in former paragraphs show that the teleutospores, or in some cases perhaps, only the promycelia delevoped from them in the tremelloid *Uredineae,* are not only very like the basidia of the *Tremellineae*, but strictly homologous with them. * * * There is the same relation between the sporidia and the basidiospores.

"The near connection which has been pointed out between the *Hymenomycetes* and the *Uredineae* may well be regarded as an established fact that is not likely to be set aside."

The truth of the keen generalization has been further strengthened by the cytological evidence of which a brief review may be permitted.

REVIEW OF THE CYTOLOGICAL WORK ON THE BASIDIOMYCETES

The present knowledge of the nuclear phenomena of rusts dates from Blackman's classic researches published in 1904 In this work he was verifying the earlier researches of Maire, who had shown that the stages of development in the rusts could be marked off as sporophytic and gametophytic. Blackman was first to show that in the aecium an actual passing of material from one basal cell to another takes place. But fusion of nuclei is delayed until the telial stage, the nuclei dividing side by side in what has been termed conjugate divisions. The details of the conjugation as described by Blackman have been shown by Christman 1905 to be peculiar to certain forms and not universal for the group. But both observers are in harmony on the presence of conjugation and the delayed fusion which follows. Olive 1908 has sought to interpret certain observations of his own to harmonize the work of Blackman and Christman with reference to the nature of the gametes, but Kurssanow 1909 has shown, using *Gymnoconia peckiana,* that the generalizations of Olive are not valid for all rusts.

It would seem then that the present views of the matter indicate a great concordance as to the presence of a conjugation and on the point of its origin. The difference in the reports is with respect to the nature of the gametes—whether isogamous or heterogamous. This difference is one that concerns itself with theories of algal relationships and does not directly concern us here.

In the higher *Basidiomycetes* there is a striking condition in that the delayed fusion that Blackman found is also present. The peculiar conjugation division of nuclei, where the paired nuclei divide side by side, is also found. The best work in this field of cytology has been done by Wager 1892, Dangeard 1894, Ruhland 1901, Harper 1902, Maire 1903, and Nichols 1904.

Ruhland 1901 found that each hymenial cell had two nuclei. The origin of these nuclei is not known altho it is strongly indicated that a long series of such binucleate cells precede this structure. In the basidium mother cell, the nuclei fuse and by two divisions produce four which pass simultaneously thru the narrow necks of the sterigmata into the spores.

Nichols 1904 found that in the spore each nucleus divides. With the germination of the spores, successive divisions take place in the germ tube, but these divisions are not of the conjugate nature found later when the nuclei are paired. Just at what point in the life-history the paired condition begins is unknown.

Until elucidation of the point of origin of the binucleate condition the similarity with the *Uredinales* can only be inferred. In this regard Harper 1910 (p. 257) says this paired condition "does not apparently result from a cell fusion at a definite point in the life cycle as is the case in the basidium of the rusts" and "it seems probable that the endokaryogamy in the basidium may have functionally replaced an older fusion of differentiated sex cells."

Recently Lutman has shown that in certain *Ustilaginales* the binucleated condition at the stage preliminary to the formation of basidiospores is prevalent and the delayed fusion is most marked, since the sporidia themselves do the conjugating.

Hence there is, so far as the observation has been pushed, this interesting similarity in nuclear behavior in all the *Basidiomycetes*—this type of intracellular fusion of nuclei after a long period of paired divisions—a thing so striking that this type of fusion has been dignified by the name endokaryogamy.

CONCLUSION

In conclusion, therefore, it may be said, that in the rusts, so far as represented by *Gymnosporangium*, we have a connection with the *Hymenomycetes* shown by some diverse lines of relationship. In the aecium we have a conjugation taking place at a definite point, but clearly establishing a binucleate condition; in the *Hymenomycetes* a quite similar condition but with the definite point of origin lacking or unknown. In the teliospore we have endokaryogamy exactly as pictured in the basidium, and subsequent reduction divisions. In addition to this cytological evidence, there is a striking parallelism of form. This latter thing De Bary has held to be of itself conclusive. Finally, as a piece of additional evidence, we have the ejection of spores identical in each, thus showing, along with this similarity of form and cell behavior, the unity of function.

SUMMARY

Brefeld had observed an ejection of spores in *Coprinus* and Zalewski had repeated the work of Brefeld with a great many species of *Agaricaceae*, but it remained for Falck and Buller to prove conclusively the ejection of spores in the *Hymenomycetes*.

The sporidia infect the apple by penetration of the cuticle and then form pycnia and aecia. The spores from the apple infect the cedar, but, as Heald has shown, the mycelium is perennial in the latter host.

The germination phenomena of the teliospores are briefly reviewed and the abnormalities of germination commented upon.

Measurements are given to show that by the swelling of the sori and of the pedicels of the spores the hymenial surface is greatly increased, but by no means so extensively as the surface in the *Hymenomycetes.*

It is possible to make spore prints from *Gymnosporangium* quite as from a mushroom and this forms an easy way of securing pure cultures of rust spores.

With the beam of light it is possible to see the spores falling from the sorus.

Light does not seem to affect the spore discharge. Dryness of the atmosphere, so long as the spores and sterigma are turgid does not hinder. Temperature within a range of from 7° C. to 30° C. has no effect. Anaesthetics stop the discharge immediately.

By four methods the discharge of spores was noted. The spores are projected from 13 to 18 times their own length.

The discharge is brought about by the turgor relations of the spore and promycelium (sterigmata), by which a mutual bulging of the parts is produced. That the pressure within the spore and sterigma is high is shown by the fact that both parts round off after the discharge.

The work merely emphasizes the connection between the *Uredinales* and the *Hymenomycetes*—a thing that had long been held on account of the similarity of structure, and which has recently been made sure by a study of the cytology of the groups —by showing that along with this similarity there is a unity of function.

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PLATE I.

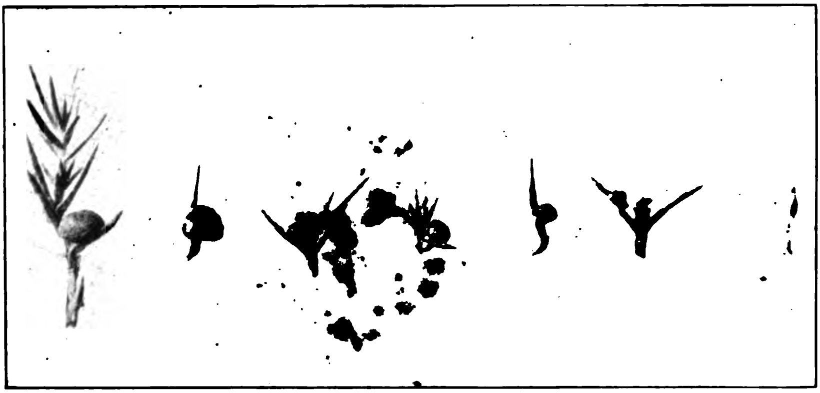

Fig. 1. Series of galls on leaves. × 2.

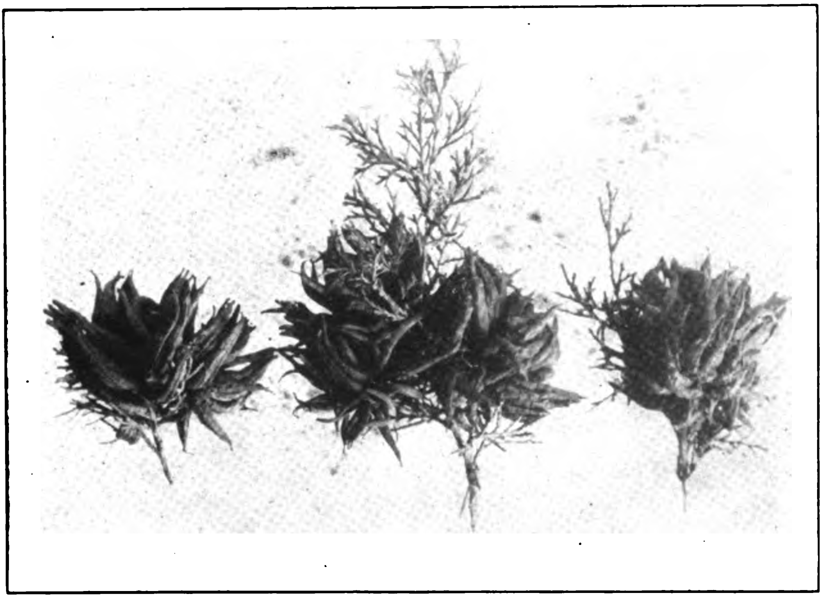

Fig. 2. Galls with swollen sori.

PLATE II.

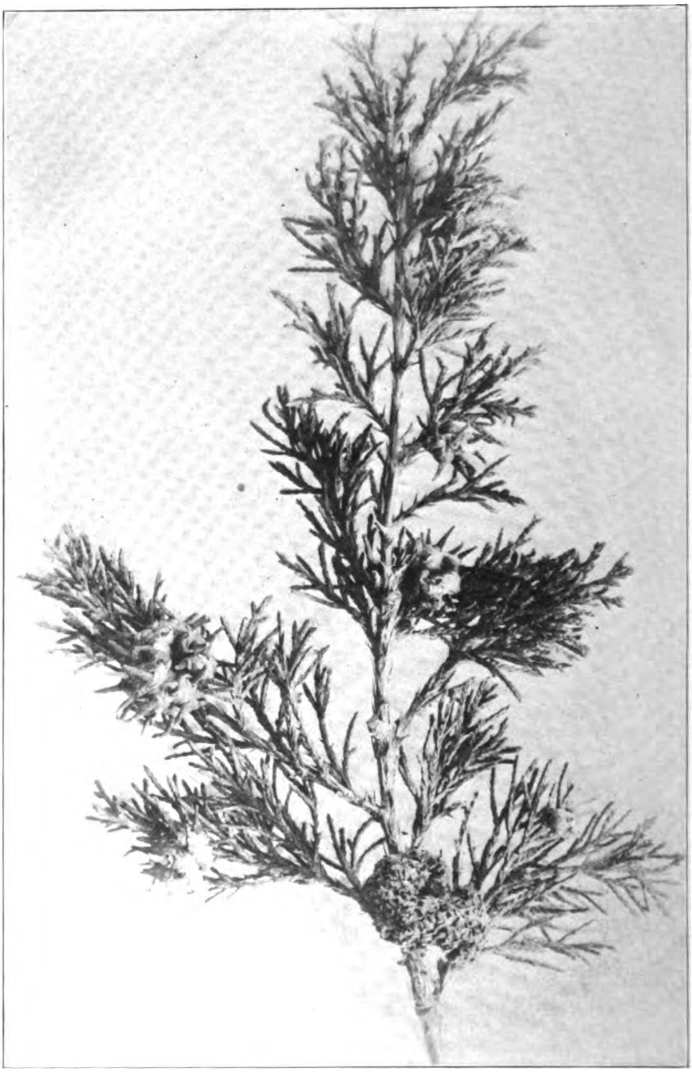

Fig. 3. Galls in March; gall of the preceding year at the base.

PLATE III.

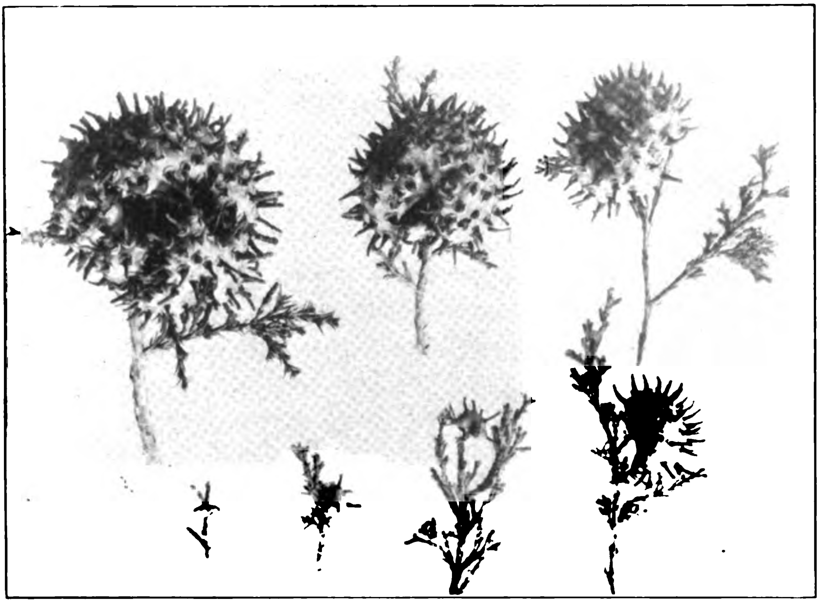

Fig. 4. Various sizes of galls—all of which are producing sori.

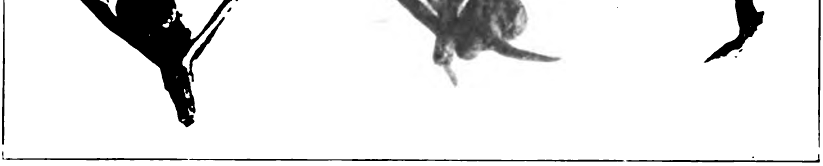

Fig. 5. Early stages in the development of galls showing their foliar origin.

A STUDY OF THE MOVEMENT OF WATER IN A UNIFORM SOIL UNDER ARTIFICIAL CONDITIONS

By F. J. Alway and V. L. Clark

It is now a well recognized fact that under favorable conditions a considerable amount of water can be stored in the subsoils of semiarid and of arid lands in such a form that it can be carried thru a prolonged dry period and later made use of by crops. This is the explanation of the surprisingly large yields that have been obtained in very dry seasons on fields which in the previous year had been kept under clean cultivation. That this can be duplicated under artificial conditions has been shown at this Experiment Station.[1]

Whether the water thus stored in the subsoil rises to the roots, or the roots penetrate to the stored water, is a question still in dispute, and one on which little experimental data have yet been published. Only a very limited amount of data is yet available as to moisture changes in the subsoil under dry farming conditions. By far the most extensive study of this nature so far published is that by Burr.[2] On various fields and plots at the North Platte Substation he has, beginning with April, 1907, determined the moisture content from month to month and from year to year, thus compiling a history of the subsoil moisture for certain of these fields and plots. The fact that both the soil and the subsoil on the North Platte farm are comparatively uniform—a rare condition on experimental. as well as on other farms—has permitted him to satisfactorily interpret the data which he has accumulated.

If the stored moisture is able to pass freely upward from foot to foot, not only will it move up to the plant roots, in case these should be confined to the portion of the soil and subsoil near the surface, but it will also reach the surface and evaporate from this unless by some method of cultivation, as for instance by mulching, this can be prevented. If such is the case the character of the surface cultivation will become all important. On the other hand, if there is but little upward movement of moisture from foot to foot, and if there should be occasion to carry stored moisture from one wet season to another thru a prolonged drouth, the dry-land farmer will need to give himself but little concern regarding the condition in which the surface soil is kept, provided only that the growth of all vegetation is prevented. The readiness with which water moves upward will determine, accordingly, whether the dry-land farmer in his attempt to store moisture by clean cultivation should direct his efforts chiefly to keeping the vegetation down or to keeping the surface soil in a certain condition—whichever condition should be found most favorable for conserving water—or whether he should give about equal attention to each.

On most fields it is difficult, from field studies, to draw satisfactory conclusions in regard to the moisture movements, unless the latter be very extensive, for the reason that the soil, from foot to foot, varies so much in properties that it is very difficult to decide, in case the moisture content at one place is found to be higher than at another, whether this is due to a movement of moisture or simply to differences in the particular samples of soil taken. This last-mentioned difficulty can be overcome by the determination of the hygroscopic coefficient of each soil sample taken. This determination, however, has regularly been omitted by almost every soil investigator. Its importance was pointed out by Hilgard long ago, the necessity of its application in moisture studies in the semiarid region was illustrated by one of the writers[3] in 1907, and recently Briggs and Shantz[4] have recognized the necessity for this or some similar determination. A good illustration of this variability of the soil of individual samples from foot to foot and from boring to boring is indicated in Table 1, which gives the hygroscopic coefficients of soil samples taken from different fields at the same time or from the same field at different times on the H O Ranch near Madrid, Nebraska.

TABLE 1.—*Hygroscopic coefficients of soil samples taken from eleven borings on the H O Ranch.*

Depth	No. 1	No. 2	No 3	No. 4	No. 5	No. 6	No 7.	No. 8	No. 9	No. 10	No. 11
Feet											
1	7.8	8.5	8.0	7.5	7.1	7.4	5.9	8.5	7.0	5.3	1.9
2	10.4	9.8	9.8	10.5	10.4	6.1	6.3	10.2	7.8	5.1	1.8
3	10.2	9.8	11.3	9.2	8.0	7.0	6.4	12.4	9.3	3.3	1.7
4	7.0	8.3	7.7	6.9	6.7	7.2	7.1	13.1	13.0	3.0	1.5
5	7.0	6.9	6.4	6.6	6.3	7.1	7.7	12.2	14.2	3.0	1.8
6	7.8	7.4	6.3	6.9	6.0	9.1	9.3	9.0	12.8	1.9	1.9
7	6.9	....	5.9	4.0	4.1	9.1	11.5	9.4	....	2.7	1.7
8	....	....	5.1	....	3.9	9.1	9.9	9.2	.	2.2	1.8
9	.....	.....	5.9	.....	2.9	7.7	9.0	9.2	.....	3.8	1.5

THE SOIL USED

Having concluded from field studies, the earliest of which have been published,[3] that but little water is lost by direct evaporation from the subsoil below the first 12 inches, we began the first experiment described below to determine the upward movement of water. Later the other related experiments were carried out with some of the same soil. One serious difficulty in the study of the movement of soil moisture under artificial conditions is that with most soils it is difficult, if not actually impossible, to get a soil placed in the cylinders or pots in a condition at all similar to that in which it occurs in the field. For this reason we selected, for the experiments described below, a subsoil that was not only representative of the subsoils of a dry-land farm but also such that it could be placed in cylinders in such a condition as to be very similar to that in which it occurs naturally. Extensive studies of this soil in pits and borings on the H O Ranch as well as in various cylinder experiments have shown that there is a very close resemblance between the condition of the soil, both in the wet and in the dry state, in the cylinders and the condition of it in the field. This soil was taken from the fourth, fifth, and sixth feet in an excavation made in a prairie field on the H O Ranch. After this subsoil reached the Experiment Station it was thoroly mixed, while dry, by shoveling. The mechanical analysis, hygroscopic coefficient, and maximum water capacity of the soil are given in Table 2. It happens that this soil has a hygroscopic coefficient not much different from the subsoil of the bench portion of the North Platte Farm referred to above. The samples from the North Platte Substation were composites from three borings, taken by one of the writers in 1908 from a prairie pasture on the bench.

TABLE 2.—*Properties of the soil used in the experiments.*

Hygroscopic coefficient	5.6
Maximum water capacity, by Hilgard method	55.0
Maximum water capacity, by Wahnschaffe method	29.9
Mechanical analysis—	*Per cent*
Gravel	2.84
Coarse sand	2.00
Medium sand	1.33
Fine sand	4.16
Very fine sand	67.11
Silt	14.16
Clay *	8.40
Hygroscopic coefficients of soil samples from bench on North Platte Substation farm -	
First foot	7.9
Second foot	6.7
Third foot	6.6
Fourth foot	5.9
Fifth foot	6.1
Sixth foot	6.6

* Determined by difference.

THE EXPERIMENTS

The soil was used in five experiments, employing galvanized iron cylinders of various lengths, to get data on the following:

1. The upward movement of water from moist soil into drier soil.
2. The downward movement from moist soil into drier soil.
3. The loss from saturated soil in contact with the natural subsoil *in situ.*
4. The upward movement in a column of soil, protected from loss below and at the sides, but fully exposed to evaporation at the surface.
5. The downward movement of water applied to the surface of a column of air-dried soil.

In the first and second experiments cylinders closed at the bottom and provided with tight-fitting covers were used. All were 2 feet long and 4 inches in diameter, except three which were 6 feet long and 6 inches in diameter. On starting the second experiment three small holes were made near the bottom of each to permit of the passage of air. These holes were not found to cause any loss of moisture by evaporation into the outside air. In the third experiment the cylinders were 3 feet long, 6 inches in diameter, and open at the bottom but provided with tight-fitting covers. In the fourth experiment they were 3 feet long, 6 inches in diameter, closed at the bottom, and without covers. In the fifth experiment they were 18 inches long, 6 inches in diameter, closed at the bottom, and provided with covers.

METHOD OF FILLING THE CYLINDERS

In experiments 1 and 2 the lower half of each cylinder was filled with soil of known moisture content and the upper half

The air-dried sample used in Series A to K was that obtained by thoroly mixing a portion of the bulk soil, which had been in contact with the dry air of the storeroom for several months, and placing this in a covered can.

The moister samples were prepared by placing a weighed quantity of the air-dried soil, of which the moisture content had been determined, on the smooth cement floor of the mixing room, and adding the calculated amount of water in small portions while the mass was being shoveled over. The whole of it was mixed thoroly, by first shoveling, then passing it twice thru a swinging sieve of one-fourth-inch mesh, and finally by again shoveling the mass thoroly. The moist soil thus prepared was immediately placed in a large covered can, in which it was kept until transferred to the cylinders. In filling the latter, a small amount of soil was added at a time and this tamped before adding more. For tamping we used a two-inch rubber stopper on the end of a three-eighths-inch gas pipe three feet long. At the time the cylinders were being filled samples were taken from the cans for moisture determinations.

The moisture percentages reported in the tables are those actually found in the soil after it had been mixed and placed in the large cans. Thus, where we desired a series of soils containing 7.0, 9.0, 11.0, 13.0, and 15.0 per cent of water respectively, we obtained, instead, a series with 7.3, 9.1, 11.1, 13.0, and 15.1 per cent, respectively. Those used containing from 5.4 to 6.2 per cent of water were made up with the intention of having the soil contain practically the maximum amount of hygroscopic moisture.

As soon as a cylinder had been filled it was closed by means of the tightly-fitting metal cover. When all the cylinders to be used at one time had been filled, they were weighed on scales sensitive to half an ounce, and placed in a pit dug in the floor of the greenhouse. The pit was covered, a foot and a half below the floor, with boards and straw and then with one foot of soil.

so as to prevent sudden or extreme variations in temperature. There was free circulation of air in the pit, and the soil of the walls and floor was moist. When it was desired to open some of the cylinders the pit was opened, and after the removal of these it was again covered up as before. The cylinders removed were at once weighed in order to determine whether there had been any loss or gain in weight while in the pit. In the case of only two of them did the scales show any change, and these two were rejected. Those placed in the pit at one time were all filled on the same day but those removed from it at one time could not, in some instances, all be opened on the same day. The latter were kept in a constant-temperature room from the time that they were taken from the pit until they were opened.

THE DETERMINATION OF THE MOISTURE

In such an experiment the removal of exactly the desired depth of soil in the case of each cylinder is a very important but difficult operation. In the first two sets the soil was removed by means of a spatula and in the last set by means of an auger provided with a gage so that just one inch at a time was taken. The soil from each inch section, after removal from the cylinder was thoroly mixed and placed in a covered jar. After all the cylinders of a set had been opened, the moisture was determined, thoroly mixing the contents of each jar before removing any soil. Two-hundred-gram samples were dried in aluminum cans in an electric oven kept at 110° C. and thru which a current of air was kept passing. In the first set, all moisture determinations were made in duplicate, but in the later ones only a single moisture determination was made of each inch section. The thoro drying of the samples being extremely important in such a study, we proceeded as follows to insure complete drying: After the samples, fifty to sixty in all, had been in the oven for twelve hours, five or six from different parts of it were removed and allowed to cool in a desiccator. These were weighed, returned to the oven, and left there for from five to twelve hours longer, when they were again weighed.. If no appreciable loss in weight had occurred during the second period of drying, we assumed that all the other samples as well were dry, they having been in the hot oven all the time. If a loss in weight had occurred, however, the drying was continued until two successive weighings showed no appreciable change in weight. After the earlier determinations. instead of using the above method of control, several 200-gram samples taken from a large sample of known moisture content were placed in the oven along with the samples from the cylinders. If, after twelve hours in the oven, these were found to be fully dried the heating was discontinued, but if not they were returned and weighed at intervals of four to twelve hours until thoroly dried, the cylinder samples being left in the oven until the control samples were dry. The former thus had a longer exposure in the oven than the latter. This modification of the control greatly shortened the time required for the drying, as usually the samples were fully dried at the end of twelve hours, thus permitting two charges instead of a single charge to be dried in twenty-four hours.

In all cases the amounts of water are expressed as percentages of the dry soil.

EXPERIMENT 1.—THE UPWARD MOVEMENT OF WATER FROM A MOIST SOIL INTO A DRIER SOIL

A summary of the experiments dealing with this subject is presented in Table 3, while the data are given in detail in Table 4. There were two parts to this experiment. The first consisted of six series of three cylinders each, with a moisture content in the soil of the lower half varying from 8.1 to 16.1 per cent, while the upper half, except in the one series, contained approximately the maximum of hygroscopic moisture. In this odd series the upper half consisted of air-dry soil. The later one consisted of four series of two cylinders each, the soil of the upper half of each being similar to that of the five series of the first set but the soil of the lower half being much more moist, the water content varying from 17.8 per cent to 27.1 per cent. One cylinder from each of two series of the second set was rejected for the reason given above. In the case of the earlier series one cylinder from each was opened after standing 115 days, while the other two were left undisturbed for 18 to 26 days longer. In the case of the later series one cylinder of each was opened at the end of 62 to 65 days and the other about one month later. The object of leaving part of each series for a longer period was to find whether any considerable movement of water took place after the opening of the first, or whether equilibrium had practically been attained.

Before considering the data in detail, the following irregularities should be pointed out: The cylinders of series A were six feet long and six inches in diameter instead of two feet long and four inches in diameter as were those of all the other series. In cylinder III, in each of Series B, C, D, E, and F, the first two inches were filled with air-dried soil, containing 3.3 per cent of water. In obtaining an average for the three cylinders of these series, the data from each of these are used along with those from the other two, as the error thereby introduced, amounting to only 0.1 per cent in the average of the whole, is negligible. altho on the average moisture content of the cylinder itself it causes an error of 0.2 per cent in the apparent change of water content. As may be seen from the tables, the average moisture content for each cylinder, as determined at the end of the experiment, indicates that in some cases there had been a slight loss and in others a slight gain between the time that the moist soil was placed in the large covered cans already referred to and the time that it was weighed out into the aluminum cans for the final moisture determinations. In some cases the apparent loss amounts to 0.5 per cent, while in others there is an apparent gain of 0.2 to 0.4 per cent. As all the cylinders reported were weighed just after being filled and again just before being opened, and as none of them showed any change in weight on scales sensitive to half an ounce, while the weight of the soil in each amounted to 15.3 to 16.9 pounds, the maximum actual loss or gain of moisture which took place while the cylinders were in the pit must have been less than 0.3 per cent. Incomplete drying of either the samples used in filling the cylinders or of those removed from the cylinders would have caused such variations, but the precautions taken, as described above, should have excluded errors from this source. This seeming gain or loss of water is rather to be attributed to the upper foot sections not weighing the same as the lower foot sections and the twenty-four samples taken on opening a cylinder varying considerably in the weight of dry soil. For this reason the actual average moisture content of the soil of the whole cylinder would not be that obtained by taking the average of the moisture contents found for the different sections. Slight losses of moisture may be attributed to evaporation occurring while the moist soil was being transferred from the large cans to the cylinders, and again at the close of the experiments, when it was being transferred from the cylinders to the jars, the air of the room in which this work was done being very dry. The instances in which a loss is shown, in both Tables 3 and 5, are more numerous than those in which a gain appears.

During the period intervening between the opening of the first of each series and the opening of the others no distinct movement of water is shown. In some series the upper foot of soil was more moist in the cylinder opened first than in that opened later, while in others the reverse was true. Hence, it is probable that equilibrium had been practically attained in the two-foot cylinders before the first was opened—at least in so far as would concern the length of time included in a single crop season. In the case of II and III of Series A, in which the cylinders were six feet long, there was, during the last 26 days, a slight but distinct, upward movement of water, but in these equilibrium could not be attained until the water content of all the soil of the upper three feet had reached 5.6 per cent—the hygroscopic coefficient.

The two-inch layer of air-dried soil at the top of III of Series B, C, D, E, and F had taken up the maximum, or almost the maximum, of hygroscopic moisture during the period of exposure.

Series A. The air-dry soil in the upper half of each cylinder had gained much in moisture, but in no part of it had the moisture content reached the hygroscopic coefficient. To furnish this water, the uppermost two inches of the lower three feet had been reduced almost to the hygroscopic coefficient. Thus a soil in excellent condition of moisture for a seed-bed had, when protected by a three-foot mulch of air-dry soil, been so dried out to a depth of three inches that seeds would not have been able to germinate in it—dried out, not by the air, but by the mulch.

Series B. With 6.1 per cent above and 8.1 per cent below, the change in the water content was limited to the portion of the soil column within three inches below and two inches above the original dividing line, except that an appreciable decrease in moisture at the top of the soil column, and a corresponding increase at the bottom, is shown.

Series C. With 6.1 per cent above and 10.1 per cent below, there had been no important change at a greater distance than five inches on each side of the original dividing line.

Series D. With 6.1 per cent above and 12.1 per cent below, an upward movement of water took place from the whole of the lower foot, affecting the dry soil above to a distance of 5 or 6 inches. In cylinder No. I there was an increase in moisture (2.0 per cent) in the upper four inches of the cylinder.

Series E. With 6.1 per cent above and 14.1 per cent below, there was an increase thruout the upper foot and an almost uniform decrease thruout the lower foot. An increase of 1.0 per cent or more occurred to only five inches above the original dividing line in two cylinders, but to the surface in the other.

Series F. With 5.9 per cent above and 16.1 per cent below, there was an almost uniform loss of 2.0 per cent thruout the lower foot and a general, but not uniform, movement thruout the upper foot.

Series G. With 6.2 per cent above and 17.8 per cent below, there was a comparatively uniform loss of about 2.2 per cent of water thruout the lower foot.

Series H. With 6.2 per cent above and 22.8 per cent below. there was an almost uniform upward movement from the lower foot of about 4.0 per cent of water. The corresponding gain in the upper foot extended to the surface but was less uniform than the change in the lower foot.

Series I. With 6.2 per cent above and 25.4 per cent below. the movement of moisture was similar to that in the preceding series but more extensive, amounting to 5.0 per cent in the lower foot.

Series J. With 6.2 per cent above and 27.1 per cent below the movement was similar to that in the preceding two series but still more extensive.

To summarize the results, it may be stated that with 10.1 per cent of water in the lower foot little upward movement took place, but with 12.1 per cent there was a distinct uniform movement of about 1.0 per cent, with 14.2 of about 1.8, with 16.1 of about 2.0, with 17.8 of about 2.2, with 22.8 of about 4.0, with 25.4 of about 5.0, and with 27.1 of about 6.0 per cent.

The most striking characteristic of the upward movement of water was the uniformity of the loss thruout the lower foot where the initial water content of this had exceeded 11 per cent. If roots had extended to the top of a foot section of the soil they could, without having entered the section, have reduced the moisture content uniformly to about 11 per cent.

TABLE 3.—*Summary of data on experiments on the upward movement of water.*

Series	Cylinder No.	Date of filling	Date of opening	Time	Initial water content			Final water content			Change in water content		
					1-12 in.	13-24 in.	1-24 in.	1-12 in.	13-24 in.	1-24 in.	1-24 in.	13-24 in.	1-24 in.
				Days	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*
A*	I	Sept. 3, 1910	Dec. 26, 1910	115	3.3	10.2	6.7	3.9	8.5	6.2†	.6	1.7	—.5†
	II	Sept. 3, 1910	Jan. 21, 1911	141	3.3	10.2	6.7	4.0	8.3	6.2†	.7	1.9	.5†
	III	Sept. 3, 1910	Jan. 21, 1911	141	3.3	10.2	6.7	4.2	8.3	6.3†	.9	1.9	—.4†
B	I	Sept. 3, 1910	Dec. 26, 1910	115	6.1	8.1	7.1	6.2	8.2	7.2	.1	.1	—.1
	II	Sept. 3, 1910	Jan. 13, 1911	133	6.1	8.1	7.1	5.9	8.0	7.0	—.1	—.1	—.1
	III	Sept. 3, 1910	Jan. 13, 1911	133	6.1‡	8.1	7.1	5.7	7.8	6.8	—.4	—.3	—.3§
C	I	Sept. 3, 1910	Dec. 26, 1910	115	6.1	10.1	8.1	6.4	9.8	8.1	.3	—.3	.0
	II	Sept. 3, 1910	Jan. 13, 1911	133	6.1	10.1	8.1	6.2	9.7	7.9	.1	—.4	—.2
	III	Sept. 3, 1910	Jan. 13, 1911	133	6.1‡	10.1	8.1	6.0	9.5	7.8	—.1	—.6	—.3§
D	I	Sept. 3, 1910	Dec. 26, 1910	115	6.1	12.1	9.1	6.7	11.0	8.9	.6	—1.1	—.2
	II	Sept. 3, 1910	Jan. 13, 1911	133	6.1	12.1	9.1	7.4	11.0	9.2	1.3	—1.1	.1
	III	Sept. 3, 1910	Jan. 13, 1911	133	6.1‡	12.1	9.1	6.4	10.7	8.6	.3	—1.4	—.5§
E	I	Sept. 3, 1910	Dec. 26, 1910	115	6.1	14.2	10.1	8.7	12.0	10.3	2.6	—2.2	.2
	II	Sept. 3, 1910	Jan. 13, 1911	133	6.1	14.2	10.1	7.3	12.3	9.8	1.2	—1.9	—.3
	III	Sept. 3, 1910	Jan. 13, 1911	133	6.1‡	14.2	10.1	7.1	12.4	9.8	1.0	—1.8	—.3§
F	I	Sept. 3, 1910	Dec. 26, 1910	115	5.9	16.1	11.0	8.0	13.4	10.7	2.1	—2.7	—.3
	II	Sept. 3, 1910	Jan. 13, 1911	133	5.9	16.1	11.0	8.7	14.1	11.4	2.8	—2.0	.4
	III	Sept. 3, 1910	Jan. 13, 1911	133	5.9‡	16.1	11.0	8.1	14.0	11.0	2.2	—2.1	.0§
G	I	Dec. 20, 1911	Feb. 20, 1912	62	6.2	17.8	12.0	8.3	15.5	11.9	2.1	—2.3	—.1
H	I	Dec. 20, 1911	Feb. 21, 1912	63	6.2	22.8	14.5	10.1	18.9	14.5	3.9	—3.9	.0
I	I	Dec. 20, 1911	Feb. 23, 1912	65	6.2	25.4	15.8	10.0	20.2	15.1	3.8	—5.2	—.7
	II	Dec. 20, 1911	March 29, 1912	100	6.2	25.4	15.8	11.4	20.5	15.9	5.2	—4.9	.1
J	I	Dec. 20, 1911	Feb. 22, 1912	64	6.2	27.1	16.6	12.3	21.1	16.7	6.1	—6.0	.1
	II	Dec. 20, 1911	March 27, 1912	98	6.2	27.1	16.6	11.8	21.1	16.4	5.6	—6.0	—.2

* The three cylinders of this series were each 6 feet long. The data given are for the third and fourth feet.

† The changes for the whole 6 feet were 0.0, 0.2 and 0.2 per cent, respectively.

‡ The uppermost two inches of this cylinder contained originally only 3.3 per cent water instead of the same as the rest of the foot.

§ An apparent loss of 0.2 to 0.3 per cent is explained by ‡.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil.*

SERIES A.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 21	Cyl. III Jan. 21	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 to 3*	3.3	3.5	3.5	3.7	3.6	....	0.3
4 to 6	3.3	3.5	3.5	3.8	3.6	....	0.3
7 to 9	3.3	3.5	3.5	3.7	3.6	....	0.3
10 to 12	3.3	3.5	3.4	3.6	3.5	....	0.2
13 to 15	3.3	3.4	3.4	3.6	3.5	....	0.2
16 to 18	3.3	3.4	3.4	3.6	3.5	....	0.2
19 to 21	3.3	3.4	3.5	3.6	3.5	....	0.2
22 to 24	3.3	3.4	3.5	3.6	3.5	....	0.2
25 to 27	3.3	3.4	3.7	3.7	3.6	....	0.3
28 to 30	3.3	3.7	3.8	4.1	3.9	....	0.6
31 to 33	3.3	4.0	4.1	4.3	4.1	....	0.8
34	3.3	4.2	4.2	4.4	4.3	....	1.0
35	3.3	4.5	4.5	4.8	4.6	....	1.3
36	3.3	4.8	4.8	4.9	4.8	....	1.5
37	10.2	5.5	5.0	5.6	5.4	4.8	....
38	10.2	6.0	6.2	5.6	5.9	4.3	....
39	10.2	7.3	6.2	6.5	6.7	3.5	....
40	10.2	9.0	8.7	8.3	8.7	1.5	....
41	10.2	9.1	8.9	8.9	9.0	1.2	....
42	10.2	9.2	9.0	8.9	9.0	1.2	....
43	10.2	9.2	9.0	9.2	9.1	1.1	....
44	10.2	9.3	9.2	9.3	9.3	0.9	....
45	10.2	9.3	9.2	9.3	9.3	0.9	....
46	10.2	9.3	9.3	9.3	9.3	0.9	....
47	10.2	9.4	9.4	9.4	9.4	0.8	....
48	10.2	9.4	9.4	9.4	9.4	0.8	....
49	10.2	9.5	9.6	9.5	9.5	0.7	....
50	10.2	9.5	9.6	9.6	9.6	0.6	....
51	10.2	9.5	9.7	9.6	9.6	0.6	....
52	10.2	9.5	9.8	9.7	9.7	0.5	....
53	10.2	9.7	9.7	9.8	9.7	0.5	....
54	10.2	9.8	9.8	9.8	9.8	0.4	....
55	10.2	9.8	9.9	9.8	9.8	0.4	....
56	10.2	9.8	9.9	9.8	9.8	0.4	....
57	10.2	9.9	9.9	9.9	9.9	0.3	....
58	10.2	10.0	9.9	10.0	10.0	0.2	....
59	10.2	10.0	10.0	10.0	10.0	0.2	....
60	10.2	10.0	10.0	10.0	10.0	0.2	....
61 to 63*	10.2	10.0	10.1	10.1	10.1	0.1	....
64 to 66	10.2	10.0	10.1	10.1	10.1	0.1	....
67 to 69	10.2	10.0	10.2	10.1	10.1	0.1	....
70 to 72	10.2	10.0	10.2	10.2	10.1	0.1	....
Average	6.7	6.7	6.9	6.9	6.8	....	. . ..

*Inclusive.

[illegible]

[illegible]

[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES B.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.1*	5.7	5.5	4.9†	5.4	0.7	....
2	6.1	6.0	5.7	4.9†	5.9	0.2	....
3	6.1	5.7	5.7	5.3	5.6	0.5	....
4	6.1	5.9	5.7	5.5	5.7	0.5	....
5	6.1	6.0	5.8	5.6	5.8	0.3	....
6	6.1	6.0	5.9	5.7	5.9	0.2	....
7	6.1	6.2	5.9	5.7	5.9	0.2	....
8	6.1	6.2	6.0	5.9	6.0	0.1	....
9	6.1	6.2	6.0	6.0	6.1	0.0	....
10	6.1	6.4	6.1	6.2	6.2	....	0.1
11	6.1	6.6	6.3	6.3	6.4	....	0.3
12	6.1	7.0	6.7	6.9	6.9	....	0.8
13	8.1	7.5	6.9	7.3	7.2	0.9	....
14	8.1	7.7	7.7	7.3	7.6	0.5	....
15	8.1	7.8	7.8	7.4	7.7	0.4	....
16	8.1	8.1	7.8	7.6	7.8	0.3	....
17	8.1	8.1	7.9	7.7	7.9	0.2	....
18	8.1	8.2	8.0	7.7	8.0	0.1	....
19	8.1	8.2	8.0	7.9	8.0	0.1	....
20	8.1	8.2	8.1	7.9	8.1	0.0	....
21	8.1	8.3	8.3	7.9	8.2	....	0.1
22	8.1	8.6	8.4	8.0	8.3	....	0.2
23	8.1	8.6	8.5	8.1	8.4	....	0.3
24	8.1	8.7	8.6	8.3	8.5	....	0.4
Average	7.1	7.2	7.0	6.8	6.9	....	....

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.3 per cent of water.

† The upper two inches were used as a composite for the determination of moisture.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES C.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.1*	5.7	5.4	5.3	5.5	0.6	....
2	6.1	5.8	5.5	5.3	5.5	0.6	....
3	6.1	5.9	5.6	5.4	5.7	0.4	....
4	6.1	5.9	5.7	5.5	5.7	0.4	....
5	6.1	5.9	5.7	5.6	5.7	0.4	....
6	6.1	6.2	5.8	5.7	5.9	0.2	....
7	6.1	6.3	6.0	5.8	6.0	0.1	....
8	6.1	6.4	6.1	6.0	6.2	....	0.1
9	6.1	6.5	6.3	6.3	6.4	....	0.3
10	6.1	6.9	6.9	6.5	6.8	....	0.7
11	6.1	7.3	7.2	7.0	7.2	....	1.1
12	6.1	7.6	7.7	7.5	7.6	....	1.5
13	10.1	9.2	9.3	7.8	8.8	1.3	....
14	10.1	9.7	9.6	9.4	9.6	0.5	....
15	10.1	9.8	9.6	9.5	9.6	0.5	....
16	10.1	9.8	9.6	9.5	9.6	0.5	....
17	10.1	9.8	9.6	9.6	9.7	0.4	....
18	10.1	9.8	9.7	9.8	9.8	0.3	....
19	10.1	9.9	9.6	9.8	9.8	0.3	....
20	10.1	9.9	9.7	9.8	9.8	0.3	....
21	10.1	9.9	9.8	9.8	9.8	0.3	....
22	10.1	9.9	9.8	9.8	9.8	0.3	....
23	10.1	9.9	9.8	9.8	9.8	0.3	....
24	10.1	9.9	9.9	9.9	9.9	0.2	....
Average	8.1	8.1	7.9	7.8	7.9	....	....

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.3 per cent of water.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES D.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.1*	5.7	8.1	5.4	6.4		0.3
2	6.1	5.7	7.6	5.4	6.2		0.1
3	6.1	5.9	8.1	5.6	6.9		0.8
4	6.1	6.1	7.3	5.7	6.4		0.3
5	6.1	6.2	6.5	5.8	6.2		0.1
6	6.1	6.3	6.3	6.0	6.2		0.1
7	6.1	6.6	6.5	6.1	6.4		0.3
8	6.1	6.9	6.7	6.4	6.7		0.6
9	6.1	7.2	7.3	6.9	7.1		1.0
10	6.1	7.6	7.7	7.3	7.5		1.4
11	6.1	8.1	8.2	7.6	7.9		1.8
12	6.1	8.5	8.6	8.2	8.4		2.3
13	12.1	9.0	9.0	8.9	9.0	3.1	
14	12.1	11.0	11.0	9.9	10.6	1.5	
15	12.1	11.1	11.1	11.0	11.1	1.0	
16	12.1	11.1	11.1	11.0	11.1	1.0	
17	12.1	11.1	11.2	10.9	11.1	1.0	
18	12.1	11.1	11.2	10.9	11.1	1.0	
19	12.1	11.1	11.1	10.9	11.0	1.1	
20	12.1	11.1	11.2	10.9	11.1	1.0	
21	12.1	11.2	11.2	11.0	11.1	1.0	
22	12.1	11.2	11.2	11.1	11.2	0.9	
23	12.1	11.2	11.2	11.1	11.2	0.9	
24	12.1	11.4	11.2	11.0	11.2	0.9	
Average	9.1	8.9	9.2	8.6	8.9		

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.3 per cent of water.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES E.

Depth of section	Cyls. I to III Sept. 3	Cyl I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.1*	7.6	6.4	5.8	6.6		0.5
2	6.1	7.7	6.6	5.9	6.7		0.6
3	6.1	7.7	6.5	6.1	6.8		0.7
4	6.1	7.7	6.1	6.2	6.7		0.6
5	6.1	7.5	6.2	6.3	6.7		0.6
6	6.1	7.4	6.4	6.4	6.7		0.6
7	6.1	7.5	6.6	6.8	6.8		0.7
8	6.1	8.0	7.3	7.4	7.6		1.5
9	6.1	8.1	8.6	8.0	8.1		2.0
10	6.1	8.7	8.4	8.4	8.5		2.4
11	6.1	9.2	8.9	8.8	9.0		2.9
12	6.1	9.3	9.2	9.0	9.2		3.0
13	14.2	10.3	9.8	9.5	9.9	4.3	
14	14.2	12.4	11.6	11.0	11.7	2.5	
15	14.2	12.5	11.7	12.6	12.2	2.0	
16	14.2	12.8	12.5	12.8	12.7	1.5	
17	14.2	12.8	12.6	12.8	12.7	1.5	
18	14.2	12.8	12.8	12.8	12.8	1.4	
19	14.2	12.8	12.6	12.8	12.7	1.5	
20	14.2	12.8	12.8	12.8	12.8	1.4	
21	14.2	12.8	12.7	12.8	12.8	1.4	
22	14.2	12.8	12.8	12.8	12.8	1.4	
23	14.2	12.8	12.8	12.7	12.8	1.4	
24	14.2	12.8	12.7	12.8	12.8	1.4	
Average	10.1	10.3	9.8	9.8	10.0		

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.3 per cent of water.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES F.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1.......	5.9[*]	7.2	7.1	6.7	7.0	....	1.1
2......	5.9	7.2	7.5	6.6	7.1	....	1.2
3.......	5.9	7.1	7.5	6.6	7.1	....	1.2
4.......	5.9	7.1	7.7	6.9	7.2	....	1.3
5.......	5.9	7.0	8.2	7.3	7.5	....	1.6
6.......	5.9	7.4	8.7	7.6	7.9	....	2.0
7.......	5.9	8.0	9.0	7.8	8.3	....	2.4
8.......	5.9	8.4	9.3	8.9	8.9	....	3.0
9.......	5.9	8.6	9.5	9.2	9.1	....	3.2
10.......	5.9	8.8	9.8	9.5	9.4	....	3.5
11.......	5.9	9.3	10.0	9.8	9.7	....	3.8
12.......	5.9	9.7	10.5	10.0	10.1	....	4.2
13.......	16.1	10.1	13.7	12.7	12.2	3.9	....
14.......	16.1	11.2	13.9	13.8	13.0	3.1	....
15.......	16.1	13.5	14.0	14.2	13.7	2.4	....
16......	16.1	13.8	14.1	14.2	14.0	2.1	....
17.......	16.1	14.1	14.2	14.0	14.1	2.0	....
18.......	16.1	14.0	14.2	14.1	14.1	2.0	....
19......	16.1	13.9	14.3	14.0	14.0	2.1	....
20......	16.1	13.9	14.2	14.2	14.1	2.0	....
21.......	16.1	14.2	14.2	14.2	14.2	1.9	....
22.......	16.1	14.3	14.3	14.6	14.4	1.7	....
23.......	16.1	13.9	14.3	14.0	14.1	2.0	....
24.......	16.1	13.9	14.3	14.2	14.1	2.0	....
Average	11.0	10.7	11.4	11.0	11.0	....	....

[*] The upper two inches of cylinder III were filled with air-dried soil carrying 3.8 per cent of water.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

	SERIES G, Cyl. I				SERIES H, Cyl. I			
Depth of section	**Dec. 20**	**Feb. 20**	**Loss**	**Gain**	**Dec. 20**	**Feb. 21**	**Loss**	**Gain**
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.2	5.6	0.6		6.2	9.0		2.8
2	6.2	5.8	0.4		6.2	9.2		3.0
3	6.2	5.9	0.3		6.2	9.1		2.9
4	6.2	6.3		0.1	6.2	9.2		3.0
5	6.2	7.0		0.8	6.2	9.3		3.1
6	6.2	7.9		1.7	6.2	9.5		3.3
7	6.2	8.7		2.5	6.2	9.8		3.6
8	6.2	9.3		3.1	6.2	10.1		3.9
9	6.2	9.8		3.6	6.2	10.6		4.4
10	6.2	10.3		4.1	6.2	11.1		4.9
11	6.2	10.7		4.5	6.2	11.5		5.3
12	6.2	12.5		6.3	6.2	13.9		7.7
13	17.8	15.4	2.4		22.8	17.5	3.3	
14	17.8	15.6	2.2		22.8	18.7	4.1	
15	17.8	15.2	2.6		22.8	18.8	4.0	
16	17.8	15.4	2.4		22.8	19.1	3.7	
17	17.8	15.5	2.3		22.8	19.2	3.6	
18	17.8	15.5	2.3		22.8	19.2	3.6	
19	17.8	15.7	2.1		22.8	19.0	3.8	
20	17.8	15.6	2.2		22.8	19.2	3.6	
21	17.8	15.6	2.0		22.8	19.1	3.7	
22	17.8	15.7	2.1		22.8	19.2	3.6	
23	17.8	15.6	2.2		22.8	19.2	3.6	
24	17.8	15.6	2.2		22.8	18.8	4.0	
Average	12.0	11.9			14.5	14.5		

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES I.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 23	Cyl. II March 29	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.2	6.8	9.7	8.3	....	2.1
2	6.2	7.4	9.8	8.8	....	2.6
3	6.2	8.1	9.9	9.0	....	2.8
4	6.2	8.8	10.2	9.5	....	3.3
5	6.2	9.4	10.4	9.9	....	3.7
6	6.2	9.9	10.7	10.3	....	4.1
7	6.2	10.2	10.9	10.5	....	4.3
8	6.2	10.7	11.4	11.0	....	4.8
9	6.2	10.9	11.7	11.3	....	5.1
10	6.2	11.3	11.9	11.6	....	5.4
11	6.2	11.7	12.8	12.2	....	6.0
12	6.2	14.9	16.9	15.9	....	9.7
13	25.4	19.2	19.7	19.4	6.0	....
14	25.4	20.2	20.3	20.2	5.2	....
15	25.4	20.2	20.1	20.2	5.2	....
16	25.4	20.2	20.0	20.1	5.3	....
17	25.4	20.4	20.7	20.5	4.9	....
18	25.4	20.3	20.5	20.4	5.0	....
19	25.4	20.4	20.4	20.4	5.0	....
20	25.4	20.4	20.7	20.5	4.9	....
21	25.4	20.6	20.6	20.6	4.8	....
22	25.4	20.8	20.8	20.8	4.6	....
23	25.4	20.8	20.7	20.8	4.6	....
24	25.4	20.3	21.5	20.9	4.5	....
Average	15.8	15.1	15.9	15.5	....	....

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Concluded.*

SERIES J.

Depth of section	Cyls. I, II Dec. 20	Cyl I Feb. 22	Cyl. II March 27	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1..........	6.2	10.5	10.7	10.6	....	4.4
2..........	6.2	10.7	10.9	10.8	....	4.6
3..........	6.2	10.8	10.8	10.8	....	4.6
4..........	6.2	11.0	Lost	11.0	....	4.8
5..........	6.2	11.0	10.9	11.0	....	4.8
6..........	6.2	11.4	11.1	11.2	....	5.0
7..........	6.2	12.0	11.2	11.6	....	5.4
8..........	6.2	12.2	11.6	11.9	....	5.7
9..........	6.2	12.7	11.9	12.3	....	6.1
10..........	6.2	12.9	12.3	12.6	....	6.4
11..........	6.2	13.8	12.6	13.2	....	7.0
12..........	6.2	18.6	16.3	17.4	....	11.2
13..........	27.1	20.9	19.3	20.1	7.0	....
14..........	27.1	21.0	20.5	20.7	6.4	....
15..........	27.1	21.1	20.5	20.8	6.3	....
16..........	27.1	21.1	20.6	20.8	6.3	....
17..........	27.1	21.1	21.1	21.1	6.0	....
18..........	27.1	21.1	21.5	21.3	5.8	....
19..........	27.1	21.1	21.5	21.3	5.8	....
20..........	27.1	21.2	21.9	21.5	5.6	....
21..........	27.1	21.3	21.8	21.5	5.6	....
22..........	27.1	21.3	21.5	21.4	5.7	....
23..........	27.1	21.4	21.6	21.5	5.6	....
24..........	27.1	21.1	21.2	21.1	6.0	....
Average ...	16.7	16.7	16.4	16.6	....	....

EXPERIMENT 2.—THE DOWNWARD MOVEMENT OF WATER FROM A MOIST SOIL INTO A DRIER SOIL

A summary of the experiments dealing with this is given in Table 5 and the data in detail in Table 6. As in the preceding experiment. there were two parts, the earlier consisting of six series of three cylinders each with a moisture content in the soil of the upper half varying from 7.3 per cent to 15.1 per cent, while that of the lower half was 5.4 per cent, except in one series where it was only 3.4 per cent. The later part consisted of five series of two cylinders each, the moisture content of the soil of the upper half varying from 15.8 to 27.1 per cent. One of the cylinders of each series was opened some time before the others of the same series.

Here, also, the average moisture content at the close indicated a gain in some cylinders and a loss in others during the course of the experiment.

In the earlier series, K to P, the soil was removed in two-inch sections instead of in inch sections.

In this experiment also there was little or no distinct movement of water downward during the interval that elapsed between the opening of the first cylinder of each series and that of the others, indicating that equilibrium had been practically attained before the first was opened.

Series K. With 9.4 per cent above and 3.4 per cent below, there was a comparatively uniform loss of 2 per cent thruout the upper foot and a gain thruout the lower foot, but not enough to raise the moisture of the latter to the hygroscopic coefficient.

Series L. With 7.3 per cent above and 5.4 per cent below, the movement was very slight.

Series M. With 9.1 per cent above and 5.4 per cent below, there was a uniform loss of about 1 per cent from the upper foot.

Series N. With 11.0 per cent above and 5.4 per cent below, there was 1.3 per cent loss from the upper foot and a gain of 1.0 per cent thruout the upper third of the lower foot but the movement did not extend below three inches.

Series O. With 13.0 per cent above and 5.4 per cent below, there was a uniform loss of about 2.0 per cent from the upper foot.

Series P. With 15.1 per cent above and 5.4 per cent below, there was a loss of 2.5 per cent or more thruout the upper foot.

Series Q. With 15.8 per cent, the foot section lost uniformly about 2.3 per cent.

Series R. With 17.8 per cent, the foot section lost uniformly about 3.0 per cent.

Series S. With 22.8 per cent, the loss reached 4.7 per cent.

Series T. With 25.4 per cent, the loss reached 5.3 per cent.

Series U. With 27.1 per cent, it reached 6.7 per cent.

On opening the cylinders the moisture in the upper foot was in all series comparatively uniformly distributed and that in the lower foot was more uniform than was the case in the upper foot in the series of the preceding experiment.

TABLE 5.—*Summary of data on experiments on the downward movement of water.*

Series	Cylinder No.	Date of filling	Date of opening	Time	Initial water content			Final water content			Change in water content		
					1-12 in.	13-24 in.	1-24 in.	1-12 in.	13-24 in.	1-24 in.	1-24 in.	13-24 in.	1-24 in.
				Days	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*
K	I	Jan. 28, 1911	April 26, 1911	88	9.4	3.4	6.4	7.6	4.4	6.0	—1.8	1.0	—0.4
	II	Jan. 28, 1911	May 2, 1911	94	9.4	3.4	6.4	7.5	4.1	5.8	—1.9	0.7	—0.6
	III	Jan. 28, 1911	May 2, 1911	94	9.4	3.4	6.4	7.5	4.3	5.9	—1.9	0.9	-0.5
L	I	Jan. 28, 1911	April 26, 1911	88	7.3	5.4	6.3	6.5	5.7	6.1	—0.8	0.3	—0.2
	II	Jan. 28, 1911	April 26, 1911	88	7.3	5.4	6.3	6.5	5.7	6.1	—0.8	0.3	—0.2
	III	Jan. 28, 1911	April 26, 1911	88	7.3	5.4	6.3	6.5	5.6	6.0	—0.8	0.2	—0.3
M	I	Jan. 28, 1911	April 26, 1911	88	9.1	5.4	7.2	8.0	5.7	6.8	—1.1	0.3	—0.4
	II	Jan. 28, 1911	May 2, 1911	94	9.1	5.4	7.2	8.0	5.9	7.0	—1.1	0.5	—0.2
	III	Jan. 28, 1911	May 2, 1911	94	9.1	5.4	7.2	8.2	6.0	7.1	—0.9	0.6	—0.1
N	I	Jan. 28, 1911	April 26, 1911	88	11.1	5.4	8.2	9.5	6.0	7.8	—1.5	0.6	—0.4
	II	Jan. 28, 1911	May 2, 1911	94	11.1	5.4	8.2	9.7	6.2	8.0	—1.3	0.8	—0.2
	III	Jan. 28, 1911	May 2, 1911	94	11.1	5.4	8.2	9.7	6.1	7.9	—1.3	0.7	—0.3
O	I	Jan. 28, 1911	April 26, 1911	88	13.0	5.4	9.2	11.0	6.5	8.7	—2.0	1.1	0.5
	II	Jan. 28, 1911	May 2, 1911	94	13.0	5.4	9.2	11.1	6.8	9.0	—1.9	1.4	—0.2
	III	Jan. 28, 1911	May 2, 1911	94	13.0	5.4	9.2	11.3	6.9	9.1	—1.7	1.5	-0.1
P	I	Jan. 28, 1911	April 26, 1911	88	15.1	5.4	10.2	12.2	7.3	9.7	-2.9	1.9	-0.5
	II	Jan. 28, 1911	May 2, 1911	94	15.1	5.4	10.2	12.6	7.2	9.9	-2.5	1.8	—0.3
	III	Jan. 28, 1911	May 2, 1911	94	15.1	5.4	10.2	12.6	7.2	9.9	-2.5	1.8	—0.3
Q	I	Dec. 20, 1911	Feb. 23, 1912	65	15.8	6.2	11.0	13.4	8.0	10.7	—2.4	1.8	—0.3
	II	Dec. 20, 1911	March 29, 1912	100	15.8	6.2	11.0	13.4	8.6	11.0	-2.4	2.4	0.0
R	I	Dec. 20, 1911	Feb. 19, 1912	61	17.8	6.2	12.0	14.9	8.4	11.7	-2.9	2.2	-0.3
	II	Dec. 20, 1911	March 18, 1912	89	17.8	6.2	12.0	14.6	8.8	11.7	3.2	2.6	—0.3
S	I	Dec. 20, 1911	Feb. 21, 1912	63	22.8	6.2	14.5	17.9	9.7	13.8	—4.9	3.5	—0.7
	II	Dec. 20, 1911	March 21, 1912	92	22.8	6.2	14.5	17.8	10.0	13.9	—5.0	3.8	—0.6
T	I	Dec. 20, 1911	March 28, 1912	99	25.4	6.2	15.8	20.1	11.8	16.0	5.3	5.6	0.2
	II	Dec. 20, 1911	March 29, 1912	100	25.4	6.2	15.8	19.6	12.3	15.9	-5.8	6.1	0.1
U	I	Dec. 20, 1911	Feb. 22, 1912	64	27.1	6.2	16.6	20.6	12.8	16.7	—6.5	6.6	0.1
	II	Dec. 20, 1911	Feb. 23, 1912	65	27.1	6.2	16.6	20.1	13.1	16.6	—6.0	5.9	0.0

TABLE 6.—*The downward movement of water from a moist soil into a drier soil.*

SERIES K.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	9.4	7.8	7.5	7.9	7.7	1.7	....
3 and 4	9.4	7.8	7.7	7.7	7.7	1.7	....
5 and 6	9.4	7.8	7.6	7.6	7.7	1.7	....
7 and 8	9.4	7.7	7.6	7.7	7.7	1.7	....
9 and 10	9.4	7.4	7.5	7.4	7.4	2.0	....
11 and 12	9.4	7.0	7.2	7.0	7.1	2.3	....
13 and 14	3.4	5.2	5.4	5.3	5.3	....	2.0
15 and 16	3.4	4.3	4.4	4.5	4.4	....	1.0
17 and 18	3.4	4.2	4.1	4.0	4.1	....	0.7
19 and 20	3.4	4.2	4.1	4.1	4.1	....	0.7
21 and 22	3.4	4.1	3.4	4.0	3.8	....	0.4
23 and 24	3.4	4.3	3.2	3.8	3.8	....	0.4
Average	6.4	6.0	5.8	5.9	5.9	....	....

SERIES L.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II April 26	Cyl. III April 26	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	7.3	6.6	6.4	6.5	6.5	0.8	....
3 and 4	7.3	6.7	6.4	6.5	6.5	0.8	....
5 and 6	7.3	6.7	6.4	6.5	6.5	0.8	....
7 and 8	7.3	6.7	6.8	6.4	6.6	0.7	....
9 and 10	7.3	6.7	6.8	6.4	6.6	0.7	....
11 and 12	7.3	5.8	6.5	6.4	6.2	1.1	....
13 and 14	5.4	5.9	5.8	5.8	5.8	....	0.4
15 and 16	5.4	5.6	5.7	5.5	5.6	....	0.2
17 and 18	5.4	5.6	5.8	5.5	5.6	....	0.2
19 and 20	5.4	5.5	5.6	5.5	5.5	....	0.1
21 and 22	5.4	5.5	5.6	5.5	5.5	....	0.1
23 and 24	5.4	5.9	5.7	5.7	5.8	....	0.4
Average	6.3	6.1	6.1	6.0	6.1	....	....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES M.

Depth of section	Cyls. I to III Jan. 26	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	9.1	8.1	8.0	8.1	8.1	1.0	....
3 and 4	9.1	8.0	7.9	8.1	8.0	1.1	....
5 and 6	9.1	8.0	8.1	8.1	8.1	1.0	....
7 and 8	9.1	8.1	8.1	8.2	8.1	1.0	....
9 and 10	9.1	7.9	8.1	8.2	8.1	1 0	....
11 and 12	9.1	7.7	7.9	8.2	7.9	1.2	....
13 and 14	5.4	6.3	6.6	7.0	6.6	....	1.2
15 and 16	5.4	5.7	6.2	6.0	6.0	....	0.6
17 and 18	5.4	5.5	5.7	5.9	5.7	....	0.3
19 and 20	5.4	5.4	5.7	5.7	5.6	....	0.2
21 and 22	5.4	5.6	5.8	5.7	5.7	....	0.3
23 and 24	5.4	5.8	5.8	5.7	5.8	....	0.4
Average	7.2	6.8	7.0	7.1	7.0	....	....

SERIES N.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	11.0	9.7	9.5	9.7	9.7	1.3	....
3 and 4	11 0	9.7	9.7	9.8	9.7	1.3	....
5 and 6	11.0	9.5	9.8	9.8	9.7	1.3	....
7 and 8	11.0	9.5	9.8	9.7	9.7	1.3	....
9 and 10	11.0	9.5	9.8	9.8	9.7	1.3	....
11 and 12	11.0	9.2	9.6	9.2	9.3	1.7	....
13 and 14	5.4	7.3	7.7	7.3	7.4	....	2.0
15 and 16	5.4	6.3	6.6	6.5	6.5	....	1.1
17 and 18	5.4	5.7	6.0	5.9	5.9	....	0.5
19 and 20	5.4	5.6	5.7	5.6	5.6	....	0.2
21 and 22	5.4	5.4	5.5	5.4	5.4	....	0.0
23 and 24	5.4	5.8	5.7	5.6	5.7	....	0.3
Average	8.2	7.8	8.0	7.9	7.9	....	....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES O.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	13.0	11.1	11.0	11.2	11.1	1.9	....
3 and 4	13.0	11.1	11.1	11.2	11.1	1.9	....
5 and 6	13.0	11.0	11.0	11.7	11.2	1.8	....
7 and 8	13.0	11.2	11.2	11.0	11.1	1.9	....
9 and 10	13.0	11.1	11.1	11.2	11.1	1.9	....
11 and 12	13.0	10.5	11.1	11.2	10.9	2.1	....
13 and 14	5.4	8.3	8.7	8.8	8.6	....	3.2
15 and 16	5.4	7.4	8.0	7.7	7.7	....	2.3
17 and 18	5.4	6.3	7.0	6.9	6.7	....	1.3
19 and 20	5.4	5.7	6.0	6.2	6.0	....	0.6
21 and 22	5.4	5.5	5.7	5.9	5.7	....	0.3
23 and 24	5.4	5.6	5.6	5.9	5.7	....	0.3
Average	9.2	8.7	9.0	9.1	8.9	....	....

SERIES P.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	15.1	12.2	12.4	12.4	12.3	2.8	....
3 and 4	15.1	12.2	12.7	12.4	12.4	2.7	....
5 and 6	15.1	12.4	12.8	12.5	12.6	2.5	....
7 and 8	15.1	12.4	12.7	12.5	12.5	2.6	....
9 and 10	15.1	12.4	12.7	12.7	12.6	2.5	....
11 and 12	15.1	11.5	12.1	12.8	11.8	3.3	....
13 and 14	5.4	8.8	9.2	8.9	9.0	....	3.5
15 and 16	5.4	8.2	8.4	8.3	8.3	....	2.9
17 and 18	5.4	7.5	7.4	7.5	7.5	....	2.1
19 and 20	5.4	6.6	6.4	6.5	6.5		1.1

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES Q.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 23	Cyl. II March 29	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	15.8	13.3	13.7	13.5	2.3	
2	15.8	13.5	13.3	13.4	2.4	
3	15.8	13.7	13.4	13.5	2.3	
4	15.8	13.7	13.5	13.6	2.2	
5	15.8	13.5	13.4	13.5	2.3	
6	15.8	13.6	13.6	13.6	2.2	
7	15.8	13.6	13.6	13.6	2.2	
8	15.8	13.5	13.5	13.5	2.3	
9	15.8	13.5	13.6	13.5	2.3	
10	15.8	13.7	13.6	13.6	2.2	
11	15.8	13.7	13.7	13.7	2.1	
12	15.8	11.8	12.5	12.2	3.6	
13	6.2	10.1	10.3	10.2		4.0
14	6.2	9.8	9.9	9.9		3.7
15	6.2	9.4	9.5	9.5		3.3
16	6.2	8.9	9.2	9.0		2.8
17	6.2	8.4	9.1	8.7		2.5
18	6.2	8.1	8.6	8.4		2.2
19	6.2	7.6	8.3	7.9		1.7
20	6.2	7.1	7.9	7.5		1.3
21	6.2	6.9	7.5	7.2		1.0
22	6.2	6.6	7.6	7.1		0.9
23	6.2	6.6	7.6	7.1		0.9
24	6.2	6.0	7.8	6.9		0.7
Average	11.0	10.7	11.0	10.9		

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES R.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 19	Cyl. II March 18	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	17.8	14.8	14.9	14.8	3.0	....
2	17.8	14.8	14.5	14.7	3.1	....
3	17.8	14.8	14.6	14.7	3.1	....
4	17.8	14.9	14.6	14.7	3.1	....
5	17.8	14.9	14.7	14.8	3.0	....
6	17.8	15.0	14.6	14.8	3.0	....
7	17.8	15.0	14.6	14.8	3.0	....
8	17.8	15.2	14.5	14.8	3.0	....
9	17.8	15.0	14.6	14.8	3.0	....
10	17.8	15.0	14.5	14.8	3.0	....
11	17.8	15.2	14.6	14.9	2.9	....
12	17.8	15.0	14.2	14.6	3.2	....
13	6.2	11.1	10.1	10.6	....	4.4
14	6.2	10.3	10.1	10.2	....	4.0
15	6.2	9.8	9.8	9.8	....	3.6
16	6.2	9.1	9.5	9.3	....	3.1
17	6.2	8.5	9.4	8.9	....	2.7
18	6.2	8.4	9.0	8.7	....	2.5
19	6.2	7.7	8.9	8.3	....	2.1
20	6.2	7.4	8.3	7.8	....	1.6
21	6.2	7.1	7.9	7.5	....	1.3
22	6.2	6.9	7.7	7.3	....	1.1
23	6.2	7.0	7.5	7.3	....	1.1
24	6.2	7.2	7.6	7.4	....	1.2
Average	12.0	11.7	11.7	11.7	....	....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES S.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 21	Cyl. II March 21	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1..........	22.8	17.1	17.1	17.1	5.7	....
2..........	22.8	18.6	18.0	18.3	4.5	....
3..........	22.8	18.0	17.8	17.9	4.9	....
4..........	22.8	18.0	17.5	17.7	5.1	....
5..........	22.8	18.2	18.2	18.2	4.6	....
6..........	22.8	18.2	18.2	18.2	4.6	....
7..........	22.8	18.2	18.0	18.1	4.7	....
8..........	22.8	18.3	18.1	18.2	4.6	....
9..........	22.8	18.2	18.2	18.2	4.6	....
10..........	22.8	18.2	18.2	18.2	4.6	....
11..........	22.8	18.2	18.0	18.1	4.7	....
12..........	22.8	15.2	14.9	15.0	7.8	....
13..........	6.2	11.4	11.1	11.3	....	5.1
14..........	6.2	11.1	10.7	10.9	....	4.7
15..........	6.2	10.9	10.6	10.7	....	4.5
16..........	6.2	10.6	10.5	10.5	....	4.3
17..........	6.2	10.3	10.1	10.2	....	4.0
18..........	6.2	10.0	9.8	9.9	....	3.7
19..........	6.2	9.6	9.7	9.6	....	3.4
20..........	6.2	9.5	9.5	9.5	....	3.3
21..........	6.2	8.9	9.5	9.2	....	3.0
22..........	6.2	8.6	9.4	9.0	....	2.8
23..........	6.2	8.3	9.4	8.8	....	2.6
24..........	6.2	8.3	9.4	8.8	....	2.6
Average ...	14.5	13.8	13.9	13.8	....	....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES T.

Depth of section	Cyls. I. II Dec. 20	Cyl. I March 28	Cyl. II March 29	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	25.4	19.4	19.8	19.6	5.8	....
2	25.4	20.4	20.2	20.3	5.1	....
3	25.4	20.2	20.0	20.1	5.3	....
4	25.4	20.4	19.7	20.0	5.4	....
5	25.4	20.3	19.7	20.0	5.4	....
6	25.4	20.2	19.8	20.0	5.4	....
7	25.4	20.2	20.0	20.1	5.3	....
8	25.4	20.0	20.0	20.1	5.3	....
9	25.4	20.5	19.9	20.0	5.4	....
10	25.4	20.3	19.9	20.2	5.2	....
11	25.4	20.4	20.0	20.1	5.3	....
12	25.4	18.9	16.6	17.7	7.7	....
13	6.2	13.5	13.2	13.3	....	7.1
14	6.2	12.3	12.8	12.5	....	6.3
15	6.2	12.1	12.6	12.3	....	6.1
16	6.2	12.0	12.4	12.2	....	6.0
17	6.2	12.1	12.0	12.1	....	5.9
18	6.2	11.8	11.9	11.9	....	5.7
19	6.2	11.6	12.0	11.8	....	5.6
20	6.2	11.3	12.0	11.7	....	5.5
21	6.2	11.5	12.2	11.8	....	5.6
22	6.2	11.3	12.2	11.8	....	5.6
23	6.2	11.3	12.3	11.8	....	5.6
24	6.2	11.3	12.1	11.7	....	5.5
Average	15.8	16.0	15.9	16.0	....	....

Table 6.—*The downward movement of water from a moist soil into a drier soil—Concluded.*

SERIES D

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 22	Cyl. II Feb. 23	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	27.1	20.7	20.0	20.3	6.8	
2	27.1	21.0	20.5	20.7	6.4	
3	27.1	20.9	20.0	20.4	6.7	
4	26.1	20.9	19.9	20.4	6.7	
5	27.1	20.6	20.2	20.4	6.7	
6	27.1	21.1	20.2	20.6	6.5	
7	27.1	20.8	20.2	20.5	6.6	
8	27.1	20.8	20.0	20.4	6.7	
9	27.1	20.5	20.0	20.3	6.8	
10	27.1	20.5	20.2	20.3	6.8	
11	27.1	20.8	20.1	20.4	6.7	
12	27.1	19.2	19.7	19.5	7.6	
13	6.2	14.0	14.1	14.0		7.8
14	6.2	13.5	14.0	13.7		7.5
15	6.2	13.2	13.5	13.3		7.1
16	6.2	13.1	13.2	13.1		6.9
17	6.2	13.0	12.8	12.9		6.7
18	6.2	12.6	12.9	12.7		6.5
19	6.2	12.6	12.9	12.7		6.5
20	6.2	12.4	12.8	12.6		6.4
21	6.2	12.3	12.7	12.5		6.3
22	6.2	12.3	12.7	12.5		6.3
23	6.2	12.6	12.9	12.7		6.5
24	6.2	12.6	12.9	12.7		6.5
Average	16.6	16.7	16.6	16.7		

EXPERIMENT 3.—THE DOWNWARD MOVEMENT OF WATER IN A SOIL COLUMN IN CAPILLARY CONNECTION WITH THE NATURAL SUBSOIL BUT PROTECTED FROM EVAPORATION

When a soil is placed in a cylinder with a perforated bottom, saturated with water, and allowed to drain, the water content is not reduced to the same point that it is when the soil is in direct connection with a large amount of dry or only fairly moist soil of similar or of finer texture.

On March 11, 1912, three cylinders 3 feet long, 6 inches in diameter, and open at both ends, were placed in holes 8 inches in diameter which were bored in the loess floor of a greenhouse. The open space surrounding each cylinder was packed very tightly with subsoil in order to hold the cylinder firmly in place. Then air-dried soil was filled into the cylinders to a depth of thirty inches, tamping it as above described. Thus, direct capillary connection could be established between the soil of the cylinder and the natural subsoil. The moisture condition of the latter at a depth of three feet was about the same as in the field. On the tamped soil a two-inch layer of gravel was placed and 15 pounds of water added as rapidly as it soaked away—about 15 hours being required. As soon as all the water had been added, the tops of the cylinders were closed with tightly-fitting covers and a layer of moist soil, eight inches in depth, placed over all to prevent any evaporation and to protect the cylinders from the heat. As the weight of air-dried soil in each cylinder was approximately 50 pounds, the added water was sufficient to have raised the moisture content to over 30 per cent if no seepage had occurred. At intervals the cylinders were opened one by one and the moisture content determined by inch sections. The data are given in Table 7. At the end of seven weeks equilibrium had not inch it did not exceed 21 per cent, while in the uppermost foot it was approximately 18 per cent. Accordingly, the soil in some of the series reported in Tables 3 and 5 was as moist as it is likely to ever be found in the field.

TABLE 7.—*Downward movement of water in a uniform soil entirely protected from evaporation but in capillary connection with the earth's soil mass. Series V. On February 15 to the cylinders filled with approximately 50 pounds of air-dried soil there was added 15 pounds of water.*

Depth of section	Cylinder I March 18	Cylinder II April 1	Cylinder III April 10
Inches	*Per cent*	*Per cent*	*Per cent*
1	17.4	18.5	17.3
2	17.2	17.8	16.9
3	17.2	17.8	17.1
4	17.7	17.8	17.2
5	18.3	17.8	17.2
6	18.1	....	17.5
7	18.0	17.9	17.6
8	18.4	18.6	18.0
9	19.1	18.8	18.3
10	18.7	19.3	18.7
11	19.2	19.6	18.8
12	19.8	19.3	18.6
13	20.0	18.9	....
14	20.4	19.7	19.1
15	20.8	20.2	19.3
16	20.2	19.3	19.4
17	20.5	20.1	19.6
18	20.7	21.9	19.8
19	20.5	20.8	19.9
20	20.7	20.5	20.3
21	21.4	21.6	20.5
22	22.5	23.1	21.1
23	23.3	22.1	21.2
24	23.7	21.8	21.6

EXPERIMENT 4.—THE MOVEMENT OF WATER IN A SOIL COLUMN FULLY EXPOSED TO EVAPORATION AT THE SURFACE

In this experiment four water-tight cylinders, 6 inches in diameter, 3 feet deep, and closed at the bottom, were sunk in holes in the greenhouse as described above, but the tops of the cylinders were placed level with the surface of the greenhouse floor and left open. On February 14, 1912, they were filled with soil containing 11.8 per cent of water. The soil was tamped in as usual, this being continued to the top in the case of two and to within an inch of the top in the case of the other two. In the latter two the top inch was filled with air-dried soil. The cylinders were so situated that the sun shone on them nearly all day, no whitewash being used on the plant house windows until near the close of the experiment. The mean daily temperature was not far from 75° F. thruout the time of the exposure, the daily maximum usually rising above 90° F.

The cylinders were examined daily for the presence of minute cracks on the surface of the packed soil of the two cylinders and of crevices around the walls of all four. As soon as cracks or crevices appeared they were filled with dry soil from the surface, so that all water lost would have to pass thru the surface soil instead of part of it escaping thru such ventilating fissures.

The humidity and the temperature of the air, as well as the temperature of the soil, were probably more favorable for rapid evaporation than is the case under field conditions in Nebraska. There was, however, but very little air movement.

The data are given in Table 8. There was a steady loss of water, it being greatest at the surface and least toward the bottom of the cylinders. At the end of 22 days no loss at all was shown by the soil near the bottom of the cylinders, but at the end of 77 days even the lowest portions had suffered a loss of about 1 per cent. A uniform upward movement similar to that mentioned above in Experiments 1 and 2 is to be observed in the case of the lowest eight to eleven inches. The soil in these cylinders, having an initial water content of 11.8 per cent, was much like that in Series D which had 12.1 per cent. After 77 days' exposure, that below the surface foot was similar to the soil in the lower half of Series A and C; hence, all further losses would be expected to take place very slowly.

In the case of III and IV, the moisture in the seventeenth and eighteenth inches is lower than either above or below. Seeking an explanation for this we found a return steam pipe below the earth floor of the greenhouse at this level, but at a distance of 14 inches.

Table 8.—*Loss of water from a uniform soil protected from all loss at the sides and below, but fully exposed to evaporation at the surface. Series W. All the cylinders were filled on February 14 with soil containing 11.8 per cent water.*

Depth of Section	Water content on opening cylinder				Loss of water			
	March 7		May 1		In 22 days		In 77 days	
	Cyl. I Surface m'lch'd	Cyl. II Surface packed	Cyl. III Surface m'lch'd	Cyl. IV Surface packed	Cyl. I	Cyl. II	Cyl. III	Cyl. IV
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	3.0	3.3	2.2	2.2	8.8	8.5	9.6	9.6
2	4.4	6.5	2.2	2.4	7.4	5.3	9.6	9.4
3	7.4	8.2	3.8	4.6	4.4	3.6	8.0	7.2
4	8.8	8.6	5.6	6.2	3.0	3.2	6.2	5.6
5	9.1	9.1	6.8	7.4	2.7	2.7	5.0	4.4
6	9.5	9.4	7.4	7.8	2.3	2.4	4.4	4.0
7	9.5	10.0	7.8	8.8	2.3	1.8	4.0	3.0
8	9.7	10.1	8.1	8.6	2.1	1.7	3.7	3.2
9	9.9	10.1	8.3	8.9	1.9	1.7	3.5	2.9
10	10.1	10.3	9.0	9.1	1.7	1.5	2.8	2.7
11	10.3	10.5	9.1	9.4	1.5	1.3	2.8	2.4
12	10.4	10.6	9.2	9.5	1.4	1.2	2.6	2.3
13	10.6	10.8	9.7	9.5	1.5	1.0	2.1	2.3
14	10.9	10.9	10.0	9.8	1.5	.9	1.8	2.0
15	11.0	11.1	10.0	10.1	1.2	.7	1.8	1.7
16	11.2	11.2	9.9	10.0	.9	.6	1.9	1.8
17	11.0	11.4	9.8	9.9	.8	.4	2.0	1.9
18	11.1	11.4	9.9	9.9	.6	.4	1.9	1.9
19	11.1	11.4	10.0	10.7	.8	.4	1.8	1.1
20	11.1	11.4	10.0	10.6	.7	.4	1.8	1.2
21	11.2	11.4	10.1	10.2	.7	.4	1.7	1.2
22	11.4	11.4	10.2	10.3	.7	.4	1.7	1.6
23	11.4	11.4	10.4	10.3	.6	.4	1.6	1.5
24	11.5	11.4	10.5	10.4	.4	.4	1.4	1.5
25	11.4	11.4	10.6	10.7	.4	.4	1.3	1.4
26	11.5	11.5	10.7	10.8	.3	.3	1.2	1.1
27	11.4	11.5	10.7	10.7	.4	.3	1.1	1.0
28	11.5	11.5	10.9	10.7	.3	.3	1.1	1.1
29	11.5	11.6	10.9	10.8	.3	.2	.9	1.1
30	11.5	11.7	11.0	10.8	.3	.1	.9	1.0
31	11.5	11.7	11.0	10.8	.3	.1	.8	1.0
32	11.5	11.7	11.0	10.8	.3	.1	.8	1.0
33	11.5	11.8	11.0	10.8	.3	.0	.8	1.0
34	11.8	11.8	11.0	10.8	.0	.0	.8	1.0
35	11.8	11.8	11.0	10.8	.0	.0	.8	1.0
36	11.8	11.8	11.0	10.8	.0	.0	.8	1.0
Average	10.3	10.6	9.2	9.4	1.5	1.2	2.6	2.4

EXPERIMENT 5.—THE DOWNWARD MOVEMENT OF WATER APPLIED TO THE SURFACE OF A COLUMN OF AIR-DRIED SOIL

In this experiment six cylinders, each 18 inches long, 6 inches in diameter, closed at the bottom, and provided with a tightly-fitting cover, were used. Twelve inches of air-dried soil containing 2.3 per cent of water was tamped into each and the volume of water, equivalent to one, two, or three inches of rain, was added to the surface in small portions as rapidly as it was absorbed, after which an inch layer of gravel was added to the surface, the cylinders covered, placed in the pit, and left undisturbed for 47 days. Then they were removed, opened, and the water determined in inch sections. The data are given in Table 9.

Where one inch of water had been added, the moisture was distributed uniformly to a depth of 3 or 4 inches, below which it decreased very rapidly, but where twice as much was added the moist soil extended to the bottom of the foot, while with three inches of added water the soil was very moist thruout.

TABLE 9.—*Distribution of water in cylinders in which different amounts of water were applied to the surface of the columns of air-dried soil, after which the cylinders were allowed to stand 47 days. The air-dried soil contained 2.3 per cent water.*

One inch water added				Two inches water added			Three inches water added		
Depth	Cyl. I	Cyl. II	Average	Cyl. I	Cyl. II	Average	Cyl. I	Cyl. II	Average
Inches	*P.ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1.......	10.8	10.6	10.7	14.7	15.5	15.1	21.7	23.2	22.4
2.......	10.3	10.4	10.3	14.3	14.6	14.4	20.1	21.1	20.6
3.......	10.3	10.1	10.2	14.1	14.3	14.2	19.7	20.3	20.0
4.......	10.3	9.8	10.1	14.2	14.4	14.3	19.8	20.2	20.0
5.......	9.3	9.4	9.3	13.4	13.9	13.6	19.5	20.3	19.9
6.	8.9	8.6	8.8	13.9	12.2	13.0	19.7	20.0	19.8
7.	7.5	7.4	7.4	13.4	12.5	12.9	19.6	19.9	19.7
8.......	5.7	5.2	5.4	12.9	11.9	12.4	19.2	18.7	18.9
9.......	5.5	4.9	5.2	12.0	11.3	11.7	17.5	16.9	17.1
10.......	4.8	4.5	4.7	11.3	11.1	11.2	16.2	15.9	16.1
11.......	4.4	4.1	4.2	11.4	11.0	11.2	15.8	15.5	15.7
12......	4.3	3.9	4.1	11.3	11.0	11.1	16.2	16.4	16.8
Av......	7.7	7.4	7.6	13.1	12.8	12.9	18.7	19.0	18.9

SUMMARY

The soil used in the experiments was typical of the subsoil of a large area of the semiarid portion of Nebraska and could be placed in the cylinders in a condition very similar to that in which it naturally occurs. It had a hygroscopic coefficient of 5.6 and the maximum water capacity was 55.

When the water content was below 10 per cent, the capillary movement of moisture in any direction was slight; but when some of the soil with a moisture content of above 10 per cent was placed in contact with the same soil containing only the maximum hygroscopic moisture, there was a practically uniform movement of water from all parts of the former into the latter, except that immediately adjoining the drier soil the change was much the greatest. The higher the water content the greater was the movement of water.

When soil with a moisture content of approximately 12 per cent was freely exposed to evaporation from the surface, no loss by capillary movement occurred to a depth of 30 inches until after the third week, but by the end of eleven weeks the loss from this depth amounted to 1.0 per cent.

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